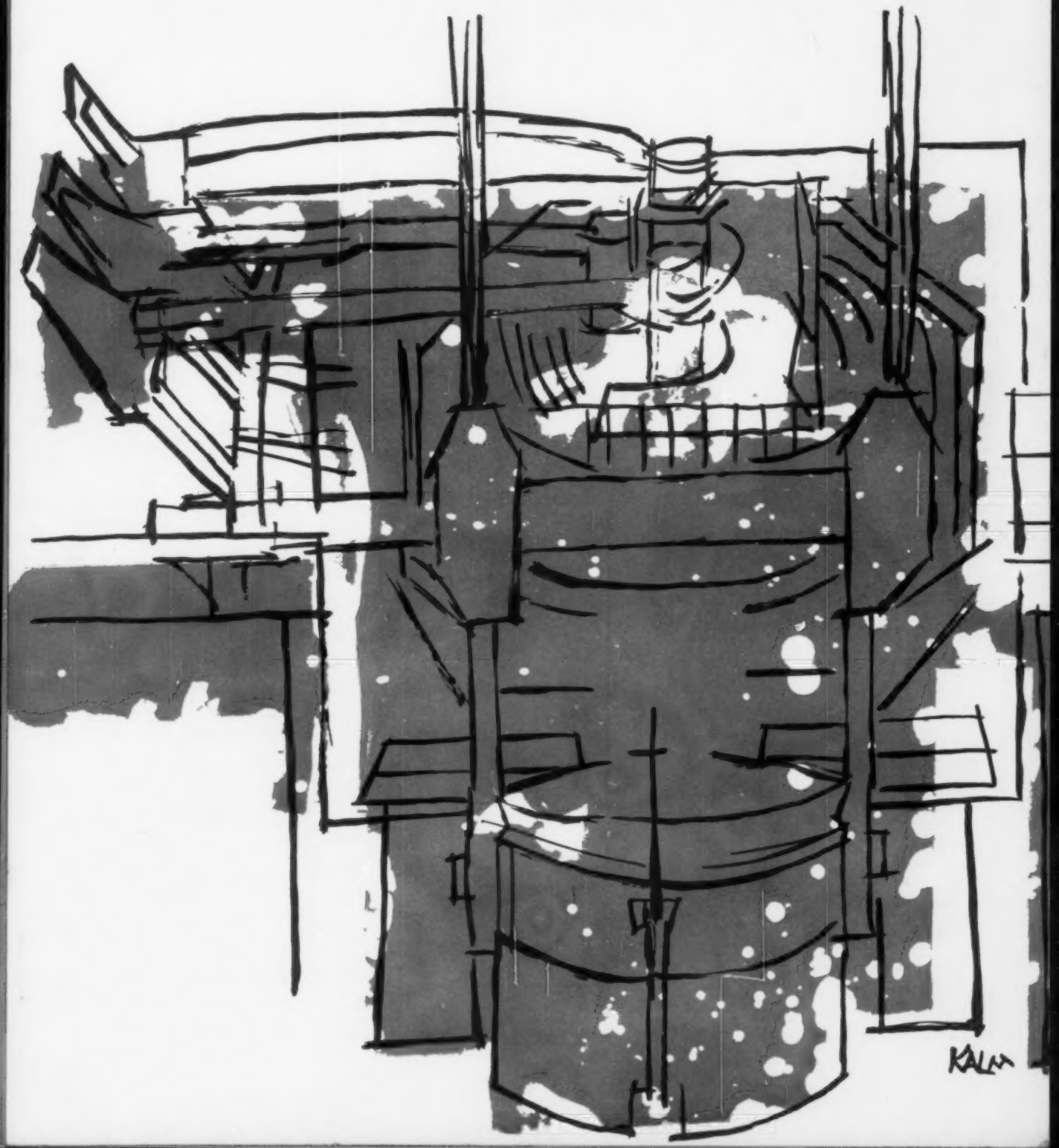
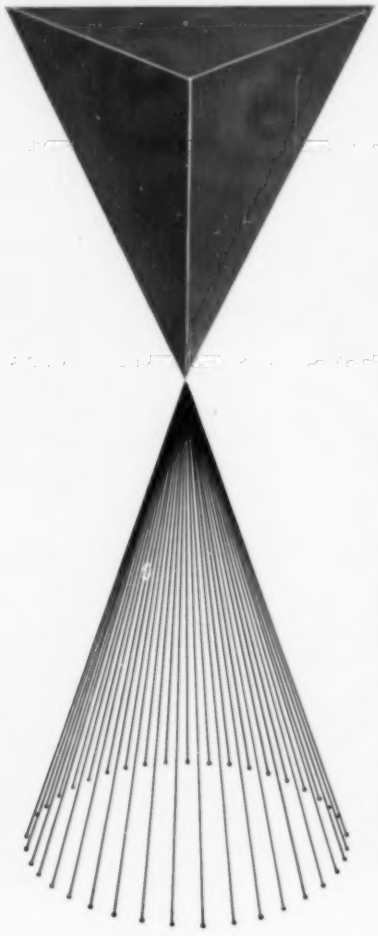
JOURNAL OF

METALS

DECEMBER 1961





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JOURNAL OF

METALS

Vol. 13, No. 12
December, 1961

COVER: Again artist Chet Kalm takes up his brush and creates—this time Christmastide on the electric furnace line.

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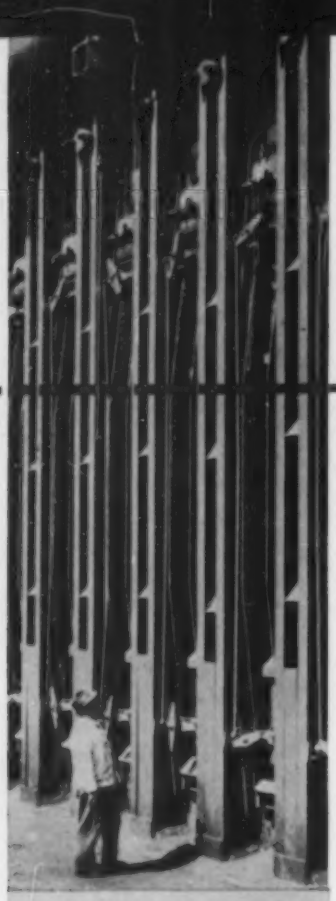


Compare these 20-foot coke oven doors with the 10 to 14 foot size now in general use in this country.

THESE TWENTY-FOOT-HIGH OVENS MAKE OVER 60% MORE COKE IN LESS SPACE, WITH LESS MANPOWER

The unique multi-stage heating system employed in these ovens causes combustion to take place over almost the full height of the flue. This permits construction and operation of ovens up to 20 feet high.

The combination of increased oven height and multi-stage heating offers important economic and operating advantages:

1. Uniform heating with a temperature difference of less than 90°F. from bottom to top of the oven walls.

2. Coal charge is homogeneously and evenly coked to make a better product.

3. Oven capacity is about 60% higher than that of a 13-foot oven.

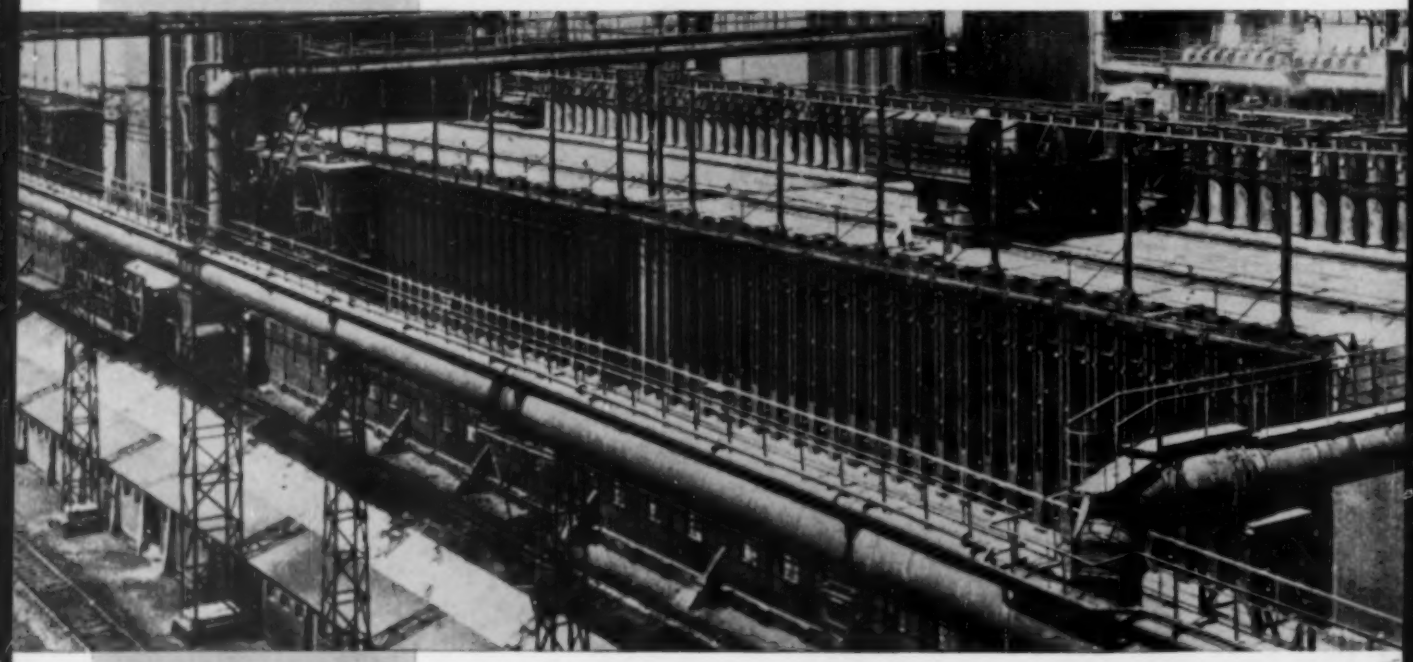
4. Coal throughput is over 40% higher per unit of battery length.

5. The taller ovens occupy about 30% less area for the same coking capacity.

6. Coke production per man is about 60% greater. Battery operating force can be reduced about 35%.

Through a license agreement with Firma Carl Still of Recklinghausen, West Germany, McKee introduces high-capacity coke ovens and complete by-product facilities of Still design on the North American continent.

If you would like complete information on how your company can increase coke production and reduce costs, contact any McKee or WKE office. We'll be glad to give you technical data on the results you can expect.



A coke plant with one hundred ninety-two 20-foot Still ovens, located in West Germany.

THE McKEE ORGANIZATION

ARTHUR G. McKEE & COMPANY, 2300 Chester Ave., Cleveland 1, Ohio. *Offices:* New York, N. Y.; Union, New Jersey; Washington, D. C.; *Subsidiaries:* Toronto and Montreal, Canada; Mexico City, Mexico; Sao Paulo, Brazil; Buenos Aires, Argentina; McKee Head Wrightson, London. WESTERN KNAPP ENGINEERING CO., 650 Fifth St., San Francisco 7, Calif. *Offices:* New York; Chicago; Hibbing, Minn.

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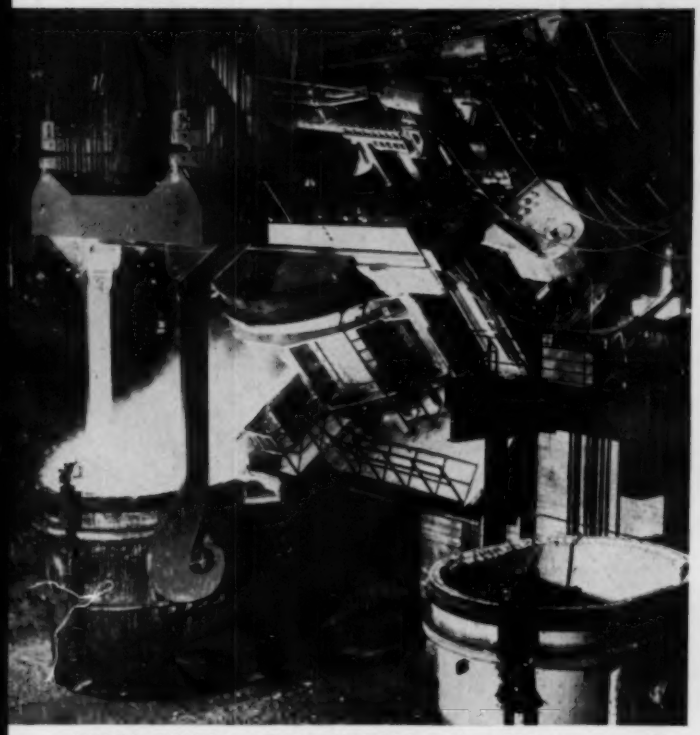
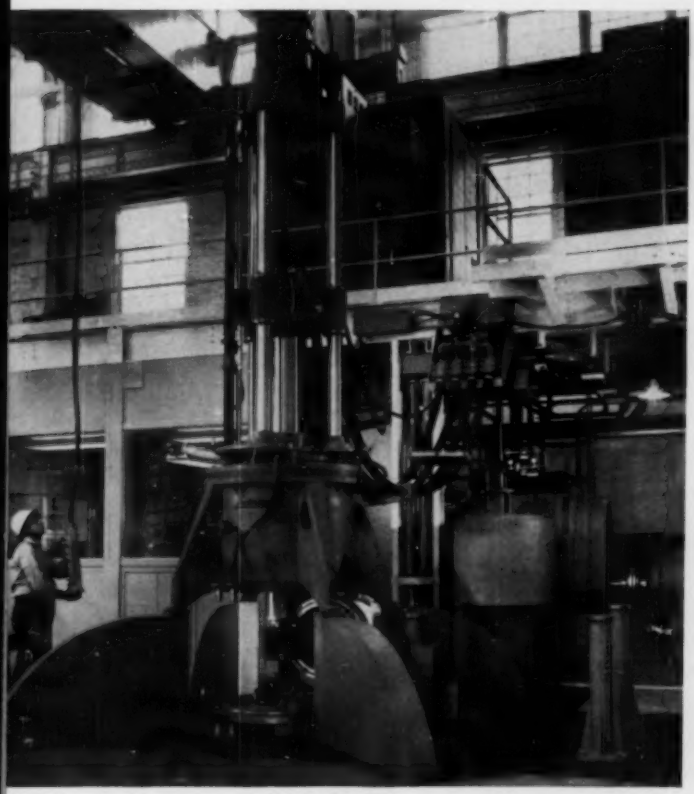
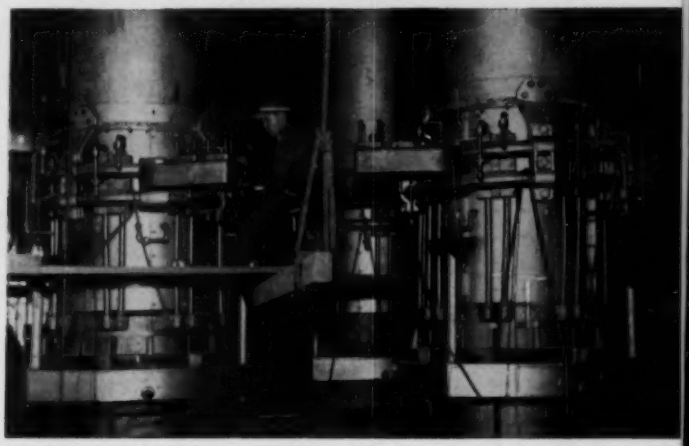


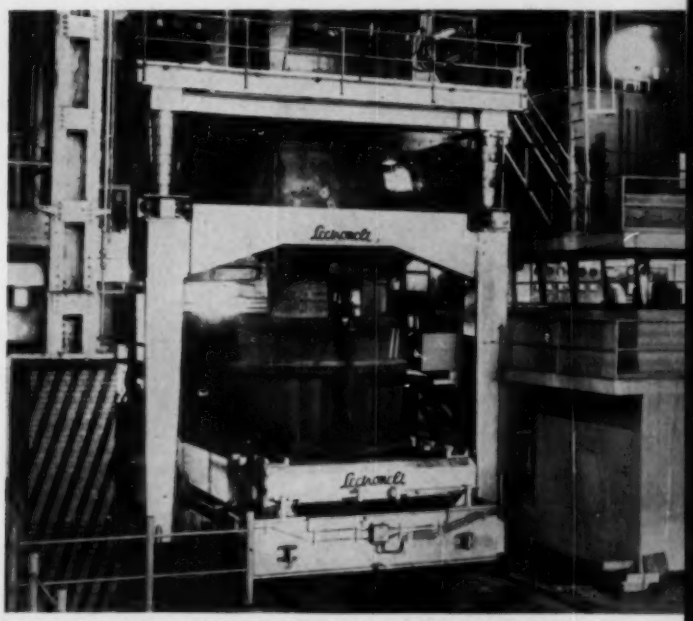
MELTING — This 24′ 0″ diameter, 200-ton capacity LECTROMELT arc furnace is pouring a heat of high-quality steel. Such heats are poured at intervals of about six hours.



VACUUM MELTING — 30″ LECTROMELT consumable-electrode vacuum-arc furnace, suitable for pouring ingots ranging from 8¾″ to 30″. Provides vacuum melting on a low-cost production basis.



SMELTING — View taken during construction of large LECTROMELT ore smelting furnace, making use of 40″ diameter self-baking electrodes. Highly efficient for the production of ferro-alloys, carbide, pig iron, etc.



VACUUM TREATMENT—LECTROMELT D-H vacuum treatment unit is highly effective for gas removal, improved cleanliness and increased yield. Developed by Dortmund-Horder-Huttenunion and Lectromelt.

Lectromelt is known for high-quality, dependable electric melting and smelting furnaces . . . with over 40 years of experience and over 2 million kilowatts of furnace capacity now in operation. Sizes up to 225 tons are available for producing steel, gray and malleable iron, for melting copper and nickel, etc. Smelting units produce pig iron, ferro-alloys, calcium carbide, phosphoric acid, etc.

Lectromelt is also known for leadership in the manufacture of equipment for vacuum melting and vacuum treatment.

Lectromelt Furnace Division, McGraw-Edison Company, Pittsburgh 30, Pa.

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personnel

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• When making application for a position, include eight cents in stamps for forwarding application to the employer and for returning, when possible.

—MEN AVAILABLE—

Metallurgical Engineer, Metallurgist, Assistant Superintendent or Superintendent, B.S. Met. Eng., age 42, married, three children. Over eleven years diversified experience supervisory and technical capacity in non-ferrous metals production, both smelting and refining. Available immediately. Will relocate. Salary open. M-264

Geologist-Mineral: Geology (Canada), age 34. $9000. Western US or Canada. Home: California. All phases mining and exploration geology. Specialize in property examination and mine evaluation. Sound education in mining and geology. Experience in asbestos, gold, uranium, and base metals. Se-1654

Metallurgist-Mine: M.S. Min. E., (Holland), age 33. $600-650. Prefer Western states. Home: Montana. Over seven years research and development, supervised testing of gold, manganese, sulfur, iron and tin ores for improvement in flowsheet, maximum recovery and efficiency, experimental work with cyclones, jigs, sieving, ore analyses, and fluorescent X-ray. Se-1403

Geologist-Industry: Geology. Age 32. Prefer foreign. Home: Texas. Single, unencumbered. Technical and commercial art background. Twelve years office procedures, report writing. Familiar with French and German. Se-1631

—POSITIONS OPEN—

Sales Engineer, metallurgical, for sales work in a gray iron foundry making a number of different alloys. Headquarters, Ohio. W937

Welding Metallurgist, B.S. Met. Eng., 25-30, with three to five years experience, to study problems needing solution, layout details, programs, and make estimates. Project activity will include establishing test procedures, taking data, analyzing results, writing reports. Will handle research projects; plan and carry programs to completion. $8000 range. Ohio. W923

Sales and Service Engineer, graduate metallurgical, chemical, or mechanical, 25-35, with experience with heavy mechanical process equipment desirable. Knowledge of mechanism and structures essential. Contact with engineering firms and utilities of heavy capital processing machinery is preferred. Initially involves field service work including mechanical service on process equipment. Some travel. $6000-$9000 plus fringe benefits. Headquarters: San Francisco, Calif. Western territory includes California, Washington, Oregon, Nevada, and Arizona. W916S

Engineers. (a) Group Leader, Metallurgical Development, with supervisory experience and strong educational background, for an aerospace-oriented metallurgical R&D section. Group is engaged in advanced programs to further the fundamental understanding of the physical metallurgy of nickel, cobalt, iron, and refractory-base alloys; basic programs in the plastic deformation and metal flow studies related to the fabrication of the refractory metals and high-strength, high-temperature alloys. (b) Leader, Advanced Fabrication, M.S. or Ph.D. in metallurgy, with several years of advanced level experience to lead plastic deformation and metal flow studies related to the fabrication of the refractory metals and the Ni-Co base superalloys. Ohio. W902

Process Engineer, degree in M.E., Met. Eng., or Metallurgy. Experience in metal processing, casting, extrusion, rolling, drawing, etc. Duties will involve work in the development of physical facilities and mechanical methods for new mill products and in the improvement of existing processes, equipment, and products. Understanding of economics of mill operations desirable. Salary $6500-$9000. Southwestern Connecticut. W884

Production Metallurgist, B.S. degree with at least five years supervisory experience in foundries making small castings. Salary open. Cleveland, Ohio area. W880

Research Metallurgist, B.S. degree, with either academic background in foundry or three years experience in foundry industry for central research laboratory. Work will involve trouble-shooting and process improvement, development, or research. R&D work that is aimed at giving better castings. $8000. New York City. W868

Metallurgical-Chemical Engineer, at least a B.S. in metallurgical or chemical engineering, with four to seven years experience in nonferrous metal and non-metallic development, processing and/or testing. Will entail the development of new products from nonferrous metal, plastics, and other new hydrocarbons, as well as the establishment and evaluation of specifications relative to the use of such materials. $9000-$11,000. Connecticut. W845

Milling-Non Metal Mill: salary open, Sierra foothills, Met. Five to fifteen years ore dress, mill, test; emphasis on non-metallics or cement. For a multi-plant cement manufacturer. Sj-6602

Field Service-Process Equipment: San Francisco, M.E., Met, Chem. Experience with heavy mechanical process equipment. Knowledge of mechanism and structures. Contact with engineering firms and utilizers of heavy capital processing machinery. To service, sell, and quote on grinding mills, rotary dryers, classifiers, feeders and related items used by mining, cement, ceramic, and industrial mineral producers and industries. For manufacturer. $6000-$9000. Sj-6611

Geologist-Non Metallic: California, Met., Geol., young. Recent graduate to one year drill mine. To survey, drill, drill samples. Single status preferred. Short term project. $500. Sj-6564

Lab Assistant-Metals: $89.60, San Francisco East Bay, to 35. Two years college or technical experience. Able to analyze iron, steel; chemical control. Prefer East Bay resident. For manufacturer of heavy equipment. Salary $89.60. Sj-6615

Address replies for positions to the nearest local office of the Engineering Societies Personnel Service, Inc., *not* to the JOURNAL OF METALS. Offices are located at 29 E. Madison St., Chicago 1, Ill. . . . 57 Post St., San Francisco, Calif. . . . and 8 W. 40th St., New York 18, N. Y.

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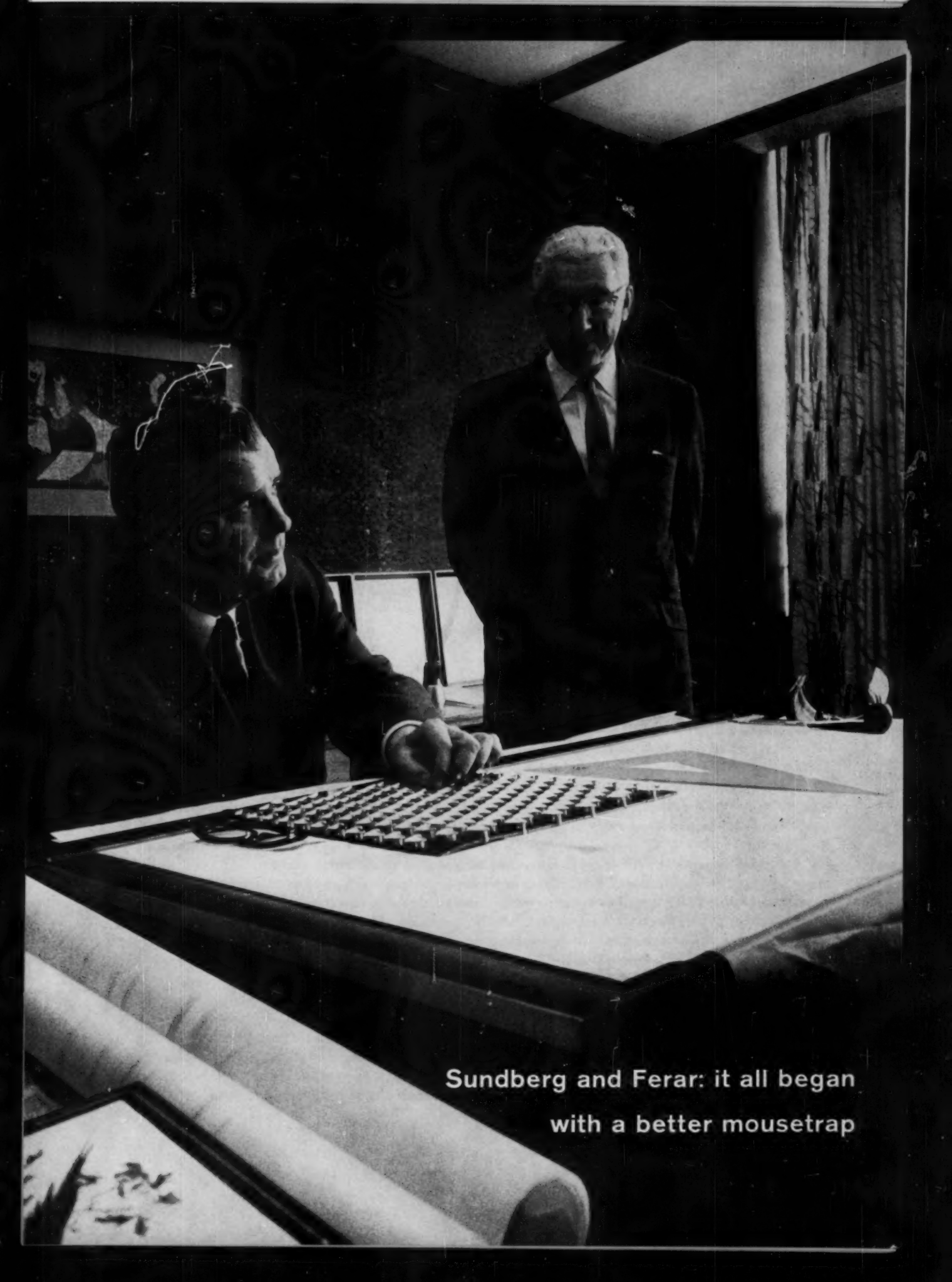


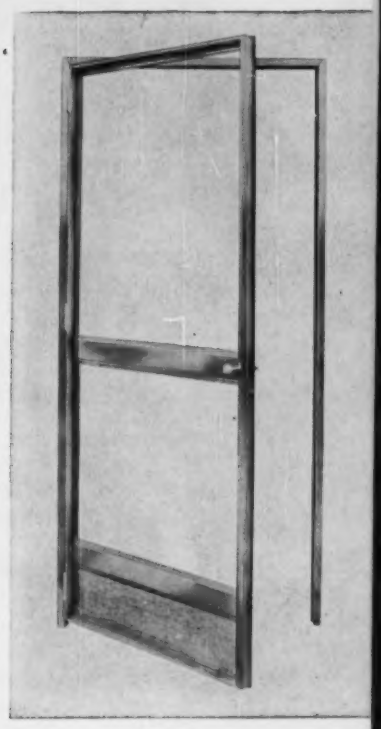
Sundberg and Ferar: it all began with a better mousetrap

Sundberg and Ferar talk design

When Carl Sundberg and Montgomery Ferar were getting their design firm started during the depths of the depression, one of their first jobs was to build a better mousetrap. It had four holes, and they called it the "Mouseoleum." It sold well, and started them on their way. Today, Sundberg-Ferar is the largest appliance design firm in the United States—7 associates and 70 designers work in an ultramodern headquarters building near Detroit. Over the years, Sundberg and Ferar have never swerved from their premise that the American public has basic good taste. Give shoppers a choice between good and bad and they'll generally pick the better-designed product.

Carl Sundberg contributes a wide range of experience to the firm with a background of art schools and factory production lines. The spectrum of their abilities approaches the complete with Monte Ferar, MIT honor graduate and holder of two degrees in architecture. Since their early days, they have designed products as varied as the clip for an automatic pencil, 5-ton trucks, factories, homes and churches. Millions of consumers are buying and using Sundberg-Ferar-designed automobiles, automatic coffee makers, refrigerators, stoves, and perfume atomizers. Sundberg-Ferar designed the cabinet for UNIVAC, the Remington-Rand computer that predicted the outcome of the 1956 Presidential election. People type on Sundberg-Ferar-designed typewriters, dig holes with draglines they developed, guide boats and airplanes with their navigational equipment, enjoy coffee and soft drinks from Sundberg-Ferar-designed dispensers.

As designers of consumer products (including most of Sears Roebuck's appliance line), Sundberg-Ferar may be the target of criticism from a current school that decries "change for the sake of change." To this observation, Sundberg-Ferar has a response: "Newness is not vulgar, despite what some critics say. Honest newness—and the improvements that go with it—is what is needed. A product can be beneficial and honest to itself—and be



new at the same time. We've got to change and improve to stay alive. In this country it is far more dangerous to be too conservative in your design than to be too advanced," says Montgomery Ferar.

How advanced are Sundberg and Ferar? Consider Monte Ferar's views on the kitchens of tomorrow: "Kitchens have come a long way since the wood-burning stoves of Grandma's day. We've gone from the ornate, to the round, to the current architectural square look. Does design history repeat itself? Not in this case. The squared-off architectural look will be with us as long as we have kitchens. As space becomes more valuable, kitchens will become smaller and we'll have to design to use all the vertical space."

As for appliances, Sundberg predicts a trend to "portable built-ins" designed to be free-standing with a built-in look. Says Ferar: "More and more, Americans are becoming mobile. We want to design our appliances so they will look built-in no matter how many times they're moved."

Ferar also sees refrigerators that will be roomier inside but no larger outside. All major appliances will be matched. "We want women to choose their appliances the same way they now choose their silver," says Ferar.

How do materials fit into the Sundberg-Ferar concept of "newness"? Few materials are newer than today's steels, and no materials are as versatile, as functional and as long-accepted as steel. It's not surprising that Carl Sundberg and Monte Ferar use a lot of steel. "A designer must *know* material—what it is, what it will do," says Carl Sundberg. "He keeps up with new developments. Materials are his clay. He must have empathy with them." About 90 percent of the products Sundberg-Ferar designs use steel because it is usually the material that is functionally suited for the job. Like most designers, they have found steel the most economical, strongest, and most versatile of the materials they use. In an average year, some 500,000 tons of steel go into Sundberg-Ferar-designed products, a far, far cry from the early days of the better mousetrap. USS is a registered trademark.

USS United States Steel

What's new in USS Design Steels

United States Steel demonstrates new alloy for cryogenic service: USS 9% Nickel Steel

CHEMICAL COMPOSITION

ASTM A-353 Grade	C	Mn	P	S	Si	Ni
A	.13 max.	.80 max.	.035 max.	.040 max.	.15/.30	8.50/9.50
B	.13 max.	.90 max.	.035 max.	.040 max.	.15/.30	8.50/9.50

DESIGN DATA

ASTM A-353 Grade	Tensile Strength psi, min.	Yield Point (0.2% offset) psi, min.	Elongation in 2 in. pct., min.	Allowable Design Stress ASME, psi, max.	Lowest Test Temp. °F. ASTM A-300
A	90,000	60,000	22	22,500	−320
B	95,000	65,000	20	23,750	−320

Modulus of Elasticity, psi — in tension.....about 29 x 10^6; in compression.....about 29 x 10^6

Burst-test for cylindrical-pressure vessels fabricated from USS 9% Nickel Steel, cooled to −320°F, then pressurized to bursting. This one was quenched and tempered—not stress relieved.

USS 9% Nickel Steel was specifically developed for low-temperature storage vessels operating down to −320°F, the boiling point of liquid nitrogen. This new steel has interesting design and money-saving possibilities for a wide range of cryogenic uses.

Recent tests at U.S. Steel's Fairless Works demonstrated the many advantages of USS 9% Nickel Steel. Called "Operation Cryogenics" and conducted jointly by United States Steel, Chicago Bridge and Iron Company and the International Nickel Company, they showed the excellent low-temperature properties of the steel, and that stress-relieving after fabrication is not necessary for vessels of either quenched and tempered 9% Nickel Steel or double-normalized and tempered 9% Nickel Steel. Pressure vessels were cooled to −320°F, then pressurized to bursting. The burst pressure for *all* vessels—stress-relieved or not—was at least *four times* the design pressure. One of the non-stress-relieved vessels did not burst until 2,300 psi. Other vessels of USS 9% Nickel Steel were refrigerated to −320°F and battered repeatedly by "headache balls" with impacts exceeding 80,000 foot-pounds. Results clearly showed that 9% Nickel Steel in the as-welded condition (not stress-relieved) can withstand impacts far beyond any which are likely to occur in service.

USS 9% Nickel Steel is the most economical material available for cryogenic storage down to −320°F which includes liquid ethylene, methane, oxygen, and nitrogen. Its initial cost is lower than either Type 304 Stainless or aluminum alloys of the 5000 series, and its excellent strength properties permit savings from the design stage to the completion of the vessel. USS 9% Nickel Steel has a high modulus of elasticity, high design stress, a low transition temperature, good ductility, ease of fabrication, good weldability and corrosion resistance. It is available in a variety of sizes and shapes: plate, tubing, bars, forgings, piping, sheets and structurals. It can be sheared, gas-cut, cold formed, forged, machined, drilled, punched, hot formed and welded. It can be furnished double normalized (NN), double normalized and tempered (NNT), quenched and tempered (QT), or in the as-rolled condition for subsequent heat treating by the fabricator.

With the trend toward storage and shipment of gas in liquid form, the demand is growing for cryogenic metals that can be fabricated into land and sea-going storage vessels, tanks, intermediate containers, piping and accessory equipment.

The success of the full-scale test program "Operation Cryogenics" is speeding the revision of low temperature codes and specifications to permit the use of quenched and tempered 9% Nickel Steel vessels without post-fabrication stress-relieving. USS 9% Nickel Steel—already more economical in the present double normalized and tempered condition than competitive metals—becomes *most* economical in the quenched and tempered and non-stress-relieved condition. Detailed information is available from United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

This mark tells you a product is made of modern, dependable Steel. People look for it on the products they buy.

USS Ex-Ten: new high strength low-cost steel

USS Ex-Ten Steels are sold to minimum mechanical properties shown in this table. Typical chemical compositions are shown for information only.

MECHANICAL PROPERTIES

	EX-TEN 45 Plates, Bars, Structurals, Bar Shapes to ¾" Incl. HR Sheets & Strip, CR Sheets	EX-TEN 50 Plates, Bars, Structurals, Bar Shapes to ¾" Incl. HR Sheets & Strip, CR Sheets	EX-TEN 55 HR Sheets & Strip
Yield Point, psi Min.	45,000	50,000	55,000
Tensile Strength, psi Min.	60,000	65,000	70,000
Elongation, Min.			
Sheets & Strip % in 2"	25	22	20
Plates & Bars % in 8"	19	18	—
Cold Bend (specimen bend)			
Sheets & Strip	Flat	D-1T	D-1½T
Plates & Bars	D-1T	D-1T	—

When hot rolled products are ordered annealed or normalized, the mechanical property requirements do not apply.

ASTM Standard Specimens; minimum number of tests and ductility modifications apply.

The newest member of the USS family of 10,000 steels is USS Ex-Ten, a high strength steel with a low initial cost that has major attributes of high strength steels and is ideal for "general range" applications requiring corrosion resistance equal to that of carbon steel.

This new steel is intended to fill the need for an economical grade where greater strength and weight reduction are the primary requirements. Suggested uses: automobile and truck parts, cargo containers, tote boxes, formed building members and many others. It has good ductility and weldability and is available in hot and cold rolled sheets and hot rolled strip, and in plates, bars, structurals, and bar shapes to a maximum thickness of ⅜ inch.

Plates and bars come in two yield strengths: Ex-Ten 50,000 and Ex-Ten 45,000 psi. Hot rolled sheets are available in 55,000, 50,000 and 45,000 psi; cold rolled sheets in 45,000 psi.

USS Ex-Ten has one of the highest strength-to-cost ratios of all steels. Further information is available from United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS Tenelon: new non-magnetic Stainless Steel for great strength and weight reduction

USS Tenelon is a completely austenitic nickel-free steel that has almost twice the yield strength of the 18-8 grades of Stainless. This enables the designer to work to higher design stresses, cut deadweight and still keep the many advantages of Stainless Steel: strength, corrosion resistance, excellent heat properties and formability.

Annealed USS Tenelon has higher mechanical properties than any of the conventional austenitic Stainless Steels. At only 5% reduction, Tenelon has a tensile strength equal to Type 301 Stainless at 18% reduction. At elevated temperatures, Tenelon is superior to 18 Cr-SNi Stainless and is about equal to 18-8 Cb and 18-8 Mo. Charpy V Notch impact strength is 220 ft. lbs. (no break) at 78° and 52 at −200°F.

The corrosion resistance of USS Tenelon has been tested in rural, industrial and marine atmospheres. In rural and industrial atmospheres it is comparable to Type 301 Stainless. In marine atmospheres, it is comparable to Type 430 Stainless. Tests have also been made in chemical plants, oil fields, dairies and even with anti-freeze, and show that Tenelon's corrosion resistance is equal to other Stainless Steels for those applications—and Tenelon is less expensive and has almost twice the strength of most conventional Stainless Steels. In mild acids, its corrosion resistance is about equal to Types 301, 302 and 201; in stronger acids, its resistance is equal to or better than Type 430.

Some suggested uses of USS Tenelon: covered hopper cars (see illustration), passenger cars, automotive vans, tank trailers, fertilizer tanks, high-tensile non-magnetic cables.

Detailed information is available on this new Stainless Steel. For a new booklet, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa. USS, Ex-Ten and Tenelon are registered trademarks

USS United States Steel

What's new in USS Design Steels

United States Steel demonstrates new alloy for cryogenic service: USS 9% Nickel Steel

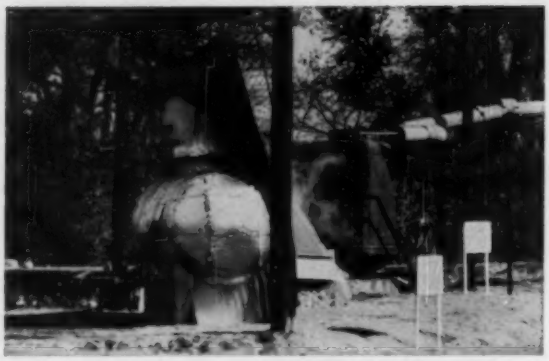
CHEMICAL COMPOSITION

ASTM A-353 Grade	C	Mn	P	S	Si	Ni
A	.13 max.	.80 max.	.035 max.	.040 max.	.15/.30	8.50/9.50
B	.13 max.	.90 max.	.035 max.	.040 max.	.15/.30	8.50/9.50

DESIGN DATA

ASTM A-353 Grade	Tensile Strength psi, min.	Yield Point (0.2% offset) psi, min.	Elongation in 2 in. pct., min.	Allowable Design Stress ASME, psi, max.	Lowest Test Temp. °F. ASTM A-300
A	90,000	60,000	22	22,500	−320
B	95,000	65,000	20	23,750	−320

Modulus of Elasticity, psi — in tension.....about 29 x 10^6; in compression.....about 29 x 10^6



Burst-test for cylindrical-pressure vessels fabricated from USS 9% Nickel Steel, cooled to −320°F, then pressurized to bursting. This one was quenched and tempered—not stress relieved.

USS 9% Nickel Steel was specifically developed for low-temperature storage vessels operating down to −320°F, the boiling point of liquid nitrogen. This new steel has interesting design and money-saving possibilities for a wide range of cryogenic uses.

Recent tests at U.S. Steel's Fairless Works demonstrated the many advantages of USS 9% Nickel Steel. Called "Operation Cryogenics" and conducted jointly by United States Steel, Chicago Bridge and Iron Company and the International Nickel Company, they showed the excellent low-temperature properties of the steel, and that stress-relieving after fabrication is not necessary for vessels of either quenched and tempered 9% Nickel Steel or double-normalized and tempered 9% Nickel Steel. Pressure vessels were cooled to −320°F, then pressurized to bursting. The burst pressure for *all* vessels—stress-relieved or not—was at least *four times* the design pressure. One of the non-stress-relieved vessels did not burst until 2,300 psi. Other vessels of USS 9% Nickel Steel were refrigerated to −320°F and battered repeatedly by "headache balls" with impacts exceeding 80,000 foot-pounds. Results clearly showed that 9% Nickel Steel in the as-welded condition (not stress-relieved) can withstand impacts far beyond any which are likely to occur in service.

USS 9% Nickel Steel is the most economical material available for cryogenic storage down to −320°F which includes liquid ethylene, methane, oxygen, and nitrogen. Its initial cost is lower than either Type 304 Stainless or aluminum alloys of the 5000 series, and its excellent strength properties permit savings from the design stage to the completion of the vessel. USS 9% Nickel Steel has a high modulus of elasticity, high design stress, a low transition temperature, good ductility, ease of fabrication, good weldability and corrosion resistance. It is available in a variety of sizes and shapes: plate, tubing, bars, forgings, piping, sheets and structurals. It can be sheared, gas-cut, cold formed, forged, machined, drilled, punched, hot formed and welded. It can be furnished double normalized (NN), double normalized and tempered (NNT), quenched and tempered (QT), or in the as-rolled condition for subsequent heat treating by the fabricator.

With the trend toward storage and shipment of gas in liquid form, the demand is growing for cryogenic metals that can be fabricated into land and sea-going storage vessels, tanks, intermediate containers, piping and accessory equipment.

The success of the full-scale test program "Operation Cryogenics" is speeding the revision of low temperature codes and specifications to permit the use of quenched and tempered 9% Nickel Steel vessels without post-fabrication stress-relieving. USS 9% Nickel Steel—already more economical in the present double normalized and tempered condition than competitive metals—becomes *most* economical in the quenched and tempered and non-stress-relieved condition. Detailed information is available from United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

This mark tells you a product is made of modern, dependable Steel. People look for it on the products they buy.

USS Ex-Ten: new high strength low-cost steel

USS Ex-Ten Steels are sold to minimum mechanical properties shown in this table. Typical chemical compositions are shown for information only.

MECHANICAL PROPERTIES

	EX-TEN 45 Plates, Bars, Structurals, Bar Shapes to ¾" Incl. HR Sheets & Strip, CR Sheets	EX-TEN 50 Plates, Bars, Structurals, Bar Shapes to ¾" Incl. HR Sheets & Strip, CR Sheets	EX-TEN 55 HR Sheets & Strip
Yield Point, psi Min.	45,000	50,000	55,000
Tensile Strength, psi Min.	60,000	65,000	70,000
Elongation, Min.			
Sheets & Strip % in 2"	25	22	20
Plates & Bars % in 8"	19	18	—
Cold Bend (specimen bend)			
Sheets & Strip	Flat	D-1T	D-1½T
Plates & Bars	D-1T	D-1T	—

When hot rolled products are ordered annealed or normalized, the mechanical property requirements do not apply.

ASTM Standard Specimens; minimum number of tests and ductility modifications apply.

The newest member of the USS family of 10,000 steels is USS Ex-Ten, a high strength steel with a low initial cost that has major attributes of high strength steels and is ideal for "general range" applications requiring corrosion resistance equal to that of carbon steel.

This new steel is intended to fill the need for an economical grade where greater strength and weight reduction are the primary requirements. Suggested uses: automobile and truck parts, cargo containers, tote boxes, formed building members and many others. It has good ductility and weldability and is available in hot and cold rolled sheets and hot rolled strip, and in plates, bars, structurals, and bar shapes to a maximum thickness of ⅝ inch.

Plates and bars come in two yield strengths: Ex-Ten 50,000 and Ex-Ten 45,000 psi. Hot rolled sheets are available in 55,000, 50,000 and 45,000 psi; cold rolled sheets in 45,000 psi.

USS Ex-Ten has one of the highest strength-to-cost ratios of all steels. Further information is available from United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS Tenelon: new non-magnetic Stainless Steel for great strength and weight reduction

USS Tenelon is a completely austenitic nickel-free steel that has almost twice the yield strength of the 18-8 grades of Stainless. This enables the designer to work to higher design stresses, cut deadweight and still keep the many advantages of Stainless Steel: strength, corrosion resistance, excellent heat properties and formability.

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Detailed information is available on this new Stainless Steel. For a new booklet, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa. USS, Ex-Ten and Tenelon are registered trademarks

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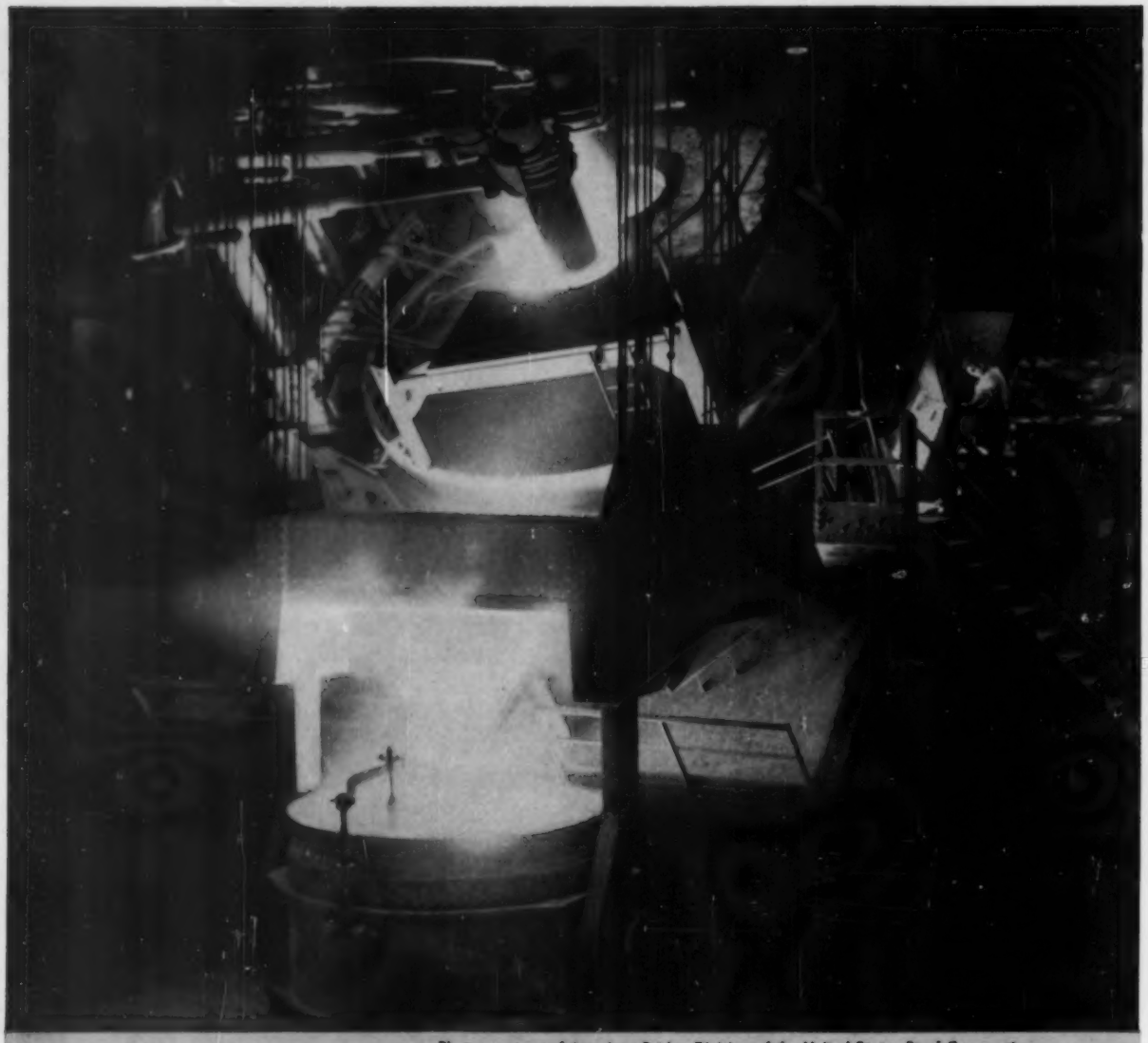

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Metals Show Highlights

Detroit's sleek and spacious Cobo Hall provided an appropriate setting for the recent Metals Show held in conjunction with the 43rd National Metal Congress and Exposition in the Motor City from October 23-27. Just as the 200,000 sq ft hall is one of the finest exhibition and convention facilities in the world, the Metals Show was bigger and better than ever. Some 30,000 registrants visited the 250 exhibits which represented the products and services of 368 metalworking companies in 11 different categories. Categories at the show included: steel, nonferrous metals, non-metallic materials, nuclear materials, tool materials, industrial heating, cleaning and finishing, and welding and joining equipment testing and control, metals production, and design and application of parts and components.

Below are some of the features of the Show thought to be of particular interest to readers of JOURNAL OF METALS:

Plasma arc weld surfacing

A new precision method for depositing fully-fused overlays of wear- and corrosion-resistant alloys, called Plasmarc weld surfacing, was demonstrated by Linde Co., div. of Union Carbide Corp. The process is said to be the first developed that can deposit a very thin fused coating with controlled dilution at high speeds. Penetration of the overlay into the base material can be held to a minimum of 0.005 in., dilution can be varied from 5 to 50 pct as desired, and more than 6 lb per hr of the material may be deposited at an efficiency of 95 pct.

High-Temperature furnace

A compact, safe, and simply operated demonstration furnace capable of producing temperatures in excess of 6000°F within seconds, was also exhibited at the Show. Built by National Carbon Co. for Baird-Atomic, the unit—known as the *Kopito Furnace*— employs a graphite cloth heating element. Electric currents, controlled by an auto-transformer, are conducted to the heating element through water-cooled carbon rolls. The specimen to be heated rests directly on the inert graphite cloth strip. Furnace temperatures reportedly return to a harmless level within 2 min after shut-off, and the graphite cloth can be handled within 15 sec after having been at maximum temperature.

New steel alloys

Three new ultra-high-strength steels for critical structural applications involving weight-saving and high-temperature resistance properties were featured by Vanadium-Alloys Steel Co. at the Show, along with *VascoJet 1000*, an alloy which already has earned wide use for critical aircraft and missile parts.

The first of the new alloys—*VascoJet M-A*—is said to be capable of achieving tensile strength values up to 360,000 psi. The two other alloys—*VascoMax 250* and *VascoMax 300 (CVM)*—both are 18 pct Ni alloys which are said to offer superior toughness and ductility at strength levels of 250,000 and 300,000 psi.

Tellurium steel

A new tellurium steel—*La-Led X*—developed by Inland Steel Co. is said to increase machining speeds about three times above conventional screw machine steels. Speeds of over 600 surface ft per min were attained with *La-Led X* in tests performed by La Salle Steel Co., and the over-all tests indicated that the tellurium-bearing steel has a machinability potential well beyond that of any present day bar stock. Tests performed on the steel included: turning, shaving, reaming, drilling, and knurling. At these high machining speeds, tool cutting feeds were also increased up to 0.0035 in. without any apparent tool wear above that normally expected.

Nickel ball anodes

A new concept of nickel plating was demonstrated at the Show by Univertical Corp. The technique consists of placing nickel-ball or beehive-type anodes in a commercially-pure titanium basket of tubular design. Instead of plating with a solid nickel anode until it becomes necessary to replace it with a fresh anode, the new method requires only the replacement of the nickel balls as the plating progresses, thus eliminating the necessity of stopping the operation. Although ball-anodes of copper, tin, brass, cadmium, and zinc have been used for plating for more than 30 years, the technique has never been applied successfully to nickel because of operating difficulties. Two such difficulties are overcome with the use of titanium for the basket; this metal does not corrode in a nickel plating solution and it does not conduct current to the solution.

H_2-Pd diffusion purifier

A new hydrogen-palladium diffusion purifier, suitable for laboratory use, was also displayed at the Metals Show. Known as *HPD-O*, the new purifier uses highly permeable palladium alloy tubing for the diffusion of hydrogen, producing the gas in ultra-pure form with no measurable impurities. The new purifier, manufactured by Engelhard Industries Inc., has a maximum flow rate of 100 cu cm per min at an inlet pressure of 50 psig and an outlet pressure of 10 psig. The company also produces larger hydrogen-palladium diffusion purifiers with outputs up to 10,000 std cfh, for use in complete systems for the production of ultra-pure hydrogen using dissociated ammonia or steam-reformed natural gas as a feed. These systems are said to provide higher purity hydrogen at substantial savings over current production methods.

REPORTER

REPORTER

Beryllium Developments

From domestic ore?

A recent discussion with an official of Brush Beryllium Co. revealed that present plant capacity is considered adequate for the market, particularly with the completion of expansion programs by both of the major US producers.

Production facilities are based upon the utilization of beryl only, and change over to another ore would require considerable modification. Beryl treatment at Brush requires making the ore amenable to dissolution by sulfuric acid in a relatively costly pyrometallurgical operation. On the other hand, treatment of the Topaz Mt. and some other domestic non-beryl ores can be accomplished directly without prior pyrometallurgical treatment. Such ores are low grade and require a relatively high utilization of acid. Nevertheless, treatment costs are estimated to be competitive with beryl.

But low-grade beryllium ores, such as those of Topaz Mt., must be treated at a location close to the deposit. And the present level of beryllium demand does not justify the capital outlay required for new ore treatment facilities in the west. Thus, only a major break-through in the beryllium market or the desire to secure ores of a vital metal in time of war would seem to justify such a capital outlay at the present time.

In regard to the flotation of Topaz Mt. ores, while such a process has been proved to be technically possible, its economic feasibility remains doubtful. When such ores are treated, Brush feels that the treatment will follow along lines of direct acid extraction.

On a small scale, Brush has successfully recovered beryllium from the Topaz Mt. ores. When the market justifies the move, the firm expects to scale-up the operation for further tests, particularly regarding the economics of extraction.

Thus, as far as Brush is concerned, its interest in the Topaz Mt. ore properties is something for tomorrow not today. FWS

Brush's expansion program

A $3-million plant which will increase beryllium fabricating capacity of the Brush Beryllium Co. by 50 pct recently started production at Cleveland, Ohio. The new facility will replace three smaller installations operated by the company in the Cleveland area.

New equipment for the plant will include about $200,000 worth of turret, engine, and tracer lathes. These machines will supplement the equipment upgraded and moved from other installations. A 120-in. King double ram vertical boring mill recently purchased by the company is the plant's largest piece of equipment.

The new plant also includes several specialized work areas apart from the general production area. One of these is for the production and quality control of test specimens as required by customers, internal control procedures, or work on research and development contracts. Another area is set aside for producing individual pieces or special configurations which do not lend themselves to standard production techniques. A special room, with temperatures controlled at 68° to 72°F, houses the extremely close tolerance machining facilities. The plant is initially employing about 325 persons, and contains 97,000 sq ft of floor space.

The new Cleveland plant is part of an over-all expansion program at Brush. The company's Elmore, Ohio plant recently completed a $6-million expansion which increased its capacity to produce basic beryllium metal from 12,000 lb per month up to 30,000 lb per month. This expansion should make this the world's largest facility for producing basic beryllium metal and should insure a more than adequate supply of beryllium.

In addition, Brush is also interested beryllides, particularly two tantalum beryllides—$TaBe_{12}$ and Ta_2Be_{17}. The company is presently working on the development of fabricating techniques. It is expected that the tantalum beryllides will soon be available in a wide variety of forms, and that additional members of the beryllide family will shortly be made available.

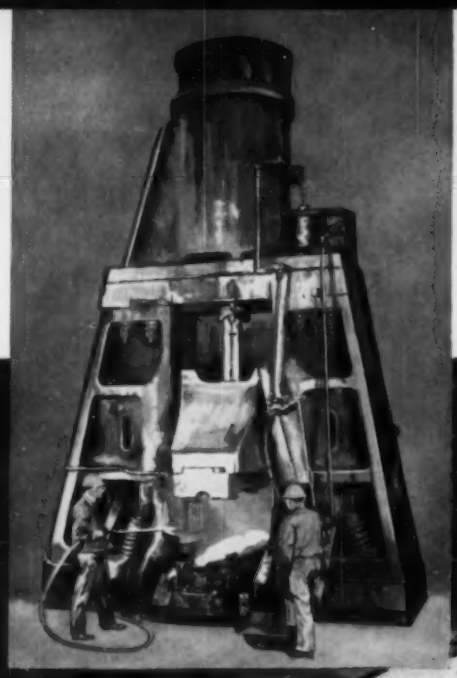
Aircraft Be Sheet

A significant step towards the expanded use of beryllium as sheathing and structural material for aircraft, missiles, and satellites was indicated when Brush Beryllium Co. was awarded an Air Force cost-sharing contract totalling $255,000 to continue its development of techniques for producing aircraft quality beryllium sheet.

Brush will produce 50 beryllium sheets in the final production phase of the program. The sheets will measure 48x18 in., 0.02, 0.04, or 0.06 in. thick, and will serve as a basis for subsequently manufactured standard aircraft size and quality 36x48 in. sheet.

The new project will concentrate particularly on surface finish, which has an important effect upon the quality of the finished sheet. New evidence gained indicates that certain heat treatments will enhance the formability of the sheet, and this will be studied further, Also to be studied will be the effect of chemical composition and crystal structure of starting beryllium billets on the results of mill-rolling procedures, and rolling variables—such as temperature, ratio and rate of reductions, cross-rolling scheduling and jacket design. In addition, flat-rolled sheets will be tested for ductile properties, and room temperature tensile strength, bend testing, and grain size will be related to this variable.

The final phases of the project include: pilot-plant production of 30 sheets 48x18 in. for fabricability and physical testing, and finally, the production of the 50 aircraft quality sheets for verification of the technology developed during the earlier phases of the 16 month project.



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Rare Earths

The Rare Earths, edited by F. H. Spedding and A. H. Daane, John Wiley & Sons, Inc., 641 pp., $14.75, 1961. *Reviewed by H. J. Bronaugh, Vitro Chemical Co.* •

Although the editors of this volume have indicated in the preface that the subject material has been derived from the papers presented at a symposium sponsored jointly by the American Society for Metals and the Atomic Energy Commission, an interested reader soon realizes that the authors have presented their particular sections with a quality and thoroughness seldom displayed at symposiums. It is apparent that the authors were chosen with the same thoughtfulness as the subject material, for each chapter has been written by men who are recognized leaders in the rare earth field.

This book, unlike past publications in the same field, devotes very little space to the historical and classical chemistry of the rare earths. These past accomplishments are accredited and referenced, as well they should be, to acquaint the initiates with the field, but the reader is quickly brought up to new concepts. The repetitive methods of separating the rare earths—ion-exchange and solvent extraction—are described and referenced in detail, with a presentation of theory as well as examples of specific separations.

The second section of the book is devoted to the preparation, purification, and fabrication of the rare earth metals. The procedures in this section are clearly defined and adequately documented with experimental data. The third section builds on the foundation of the preceding section and presents the physical properties, physical metallurgy, and phase diagrams of the rare earth metals. The chapter on the principle of alloying behavior will be of considerable help to those experimenters just beginning to investigate rare earth alloy systems.

The last section is concerned with the applications of the metals and compounds of the series, ranging from ferrous and nonferrous alloys, through applications in the glass, ceramic, and nuclear industry.

The editors have accomplished the stated purpose of presenting a review of the current work in the rare earth field which will be a valuable reference book for the chemist, physicist, and metallurgist.

Nuclear Engineering

Werkstoffkunde der Kerntechnik (in German), by W. Epprecht, Birkhauser Verlag (publishers), Basel, Switzerland and Stuttgart, Germany, 407 pp., $17.25, 1961. *Reviewed by Henry H. Hausner, consulting engineer.* •

During the last few years many books dealing with nuclear reactor materials have been published. The majority of these books have either reviewed or copied the immense report literature, with the result that the same information is given in several different books, sometimes with identical wording for several pages. Inasmuch as a review of the report literature is usually done in a non-critical way, the personality of the author of such books is hardly recognizable.

This is definitely not so with the book *Wergstoffkunde der Kerntechnik* (Technology of Materials in Nuclear Engineering, by W. Epprecht; throughout his book one can recognize the personality of the author. Dr. Epprecht is a very well known professor of metallurgy of the Swiss Institute of Technology in Zurich. In his book, he has not only reviewed the existing literature in a critical way, but he has actually given a modern theory of materials in terms of solid-state physics, as applied to nuclear materials, and has discussed their properties with respect to structure and crystal configuration. Epprecht's book represents a most advanced treatise in the physical metallurgy of nuclear materials, a valuable fundamental contribution. It is highly recommended that the book be translated into English.

This book, which contains 52 tables, 141 figures, and 321 references, may be ordered from Stechert-Hafner Inc., 31 East 10 St., New York 3, N. Y.

Oxygen in the Electric Furnace

The Use of Oxygen in the Electrometallurgy of Steel, by G. M. Borodulin, Pergamon Press, 120 pp., $8.50, 1961. *Reviewed by C. E. Sims, Battelle Memorial Institute.* •

This book is devoted almost completely to Soviet practice and technology revolving around the use of oxygen in electric furnace steelmaking. The use of oxygen began in 1948, and it is now used widely, both for hastening the melt-down period and for decarburizing during the refining operation. Both submerged blowing with refractory-covered lances and surface blowing with jets from water-cooled lances are used. The first section covers the melting and refining practice for various steels ranging from the stainless and other high-alloy through the low-alloy to the carbon steels. These practices and the technology back of them are given in considerable detail and include typical heat logs. One of the problems is in obtaining a high recovery of alloy in the scrap while carrying out a dephosphorization reaction. Two-slag practice appears to be standard, with many heats having one or more partial slag removals in addition to one complete removal. Time, charge to tap, ranges from 4 to 6 hours for 25-ton heats.

In no case was the use of oxygen found to hurt the quality of the steel, and sometimes it caused improvement. Oxygen is credited with giving a somewhat lower content of hydrogen, nitrogen, sulfur, and nonmetallic inclusion content in the steels.

The technico-economic aspects of oxygen use are considered in detail. Definite economic advantages are claimed: greater productivity, the saving of power, and increased alloy scrap consumption. These savings are reduced to the common denominator of cost in rubles. For example, in melting of 300 type stainless steel, the saving may be as high as 445 rubles per ton.

Mechanization of electro-furnace operations is described with particular attention to mechanical fettling devices, pneumatic electrode clamps, and magnetic stirrers.

Finally, there is a short section on safety factors in the use of oxygen.

• • •

Thermoelectric Materials and Devices, edited by Irving B. Cadoff and Edward Miller, Reinhold Publishing Corp., 335 pp., $9.75, 1960 •

This book is a survey of recent progress made in the development of new materials for thermoelectric devices, and is based on a series of lectures presented at New York University. The book features the contributions of 20 experts and ranges from basic theory to device design.

The first section is devoted to the theory of thermoelectric processes and thermoelectric circuits. This is followed by a general evaluation of materials, both theoretical and experimental, for use as thermoelements. Ensuing chapters discuss materials currently being used and those being considered for future

(Continued on page 870)

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scannings

More Researchers Than We Know

Perched aloft in our new tower of metals [and other materials which we don't mention] may not be equivalent to *sitting in an ivory tower*, but we do find ourselves with an ever-greater appreciation of research. Not only did it produce the where-with-all to get us up here in the air, but it is the basis of much of our AIME membership.

So, we were happy to read in a document recently put out by the National Science Foundation that, "about 331,000 scientists and engineers were employed in research and development work in the United States in 1958, an increase of 48 pct over 1954 . . . Industry employs the largest number of R&D scientists [we'd be happier if they would refer more frequently to engineers too. Ed.] with colleges and universities next, and the Government a close third. . As could be expected from the large concentration of effort in recent years on technology and innovation, engineers employed in research and development accounted for the largest portion, 63 pct or 209,000, of all scientists and engineers employed in 1958."

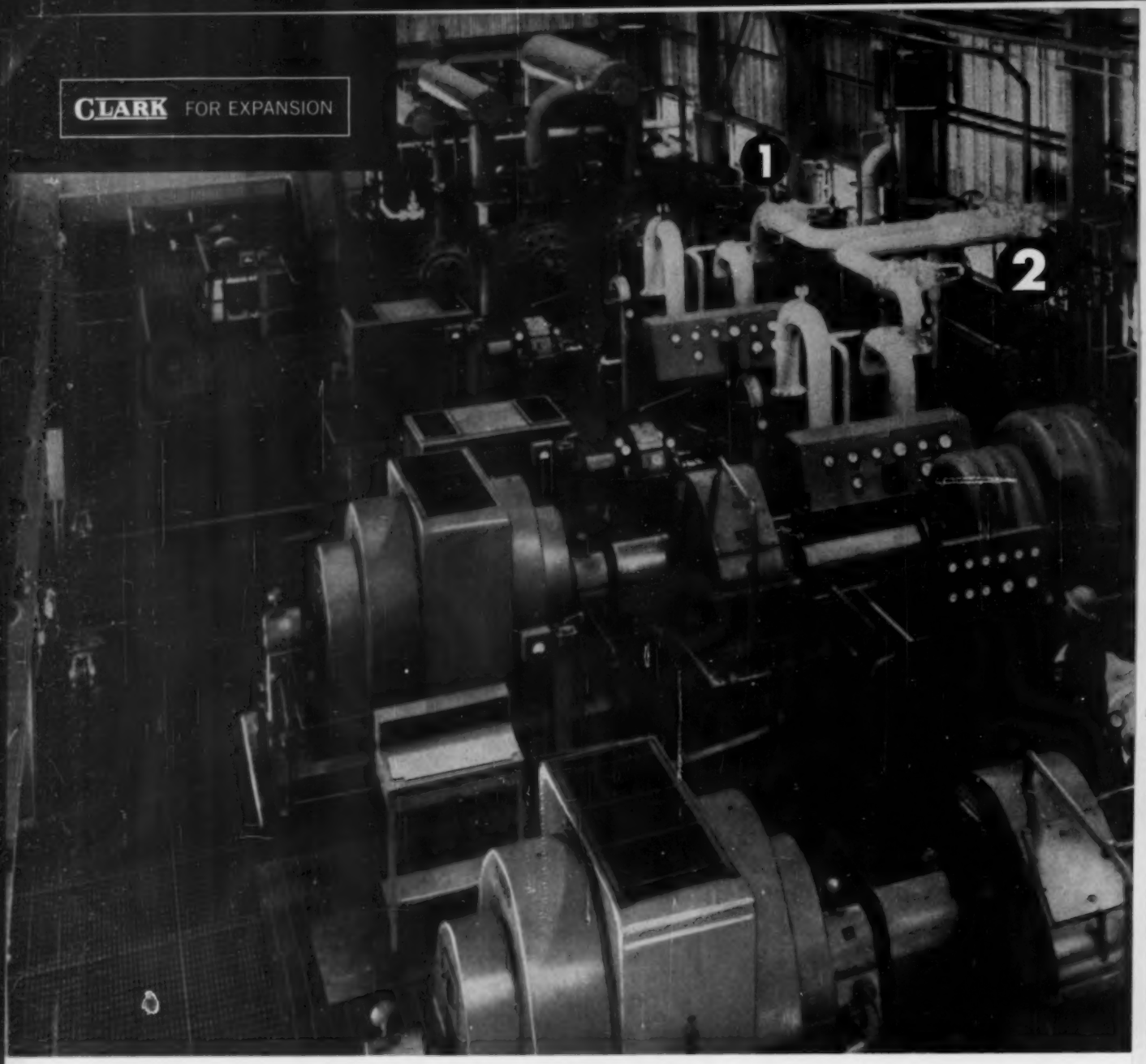
The report doesn't tell us what has happened to the trend during the ensuing three years, and without waiting until 1964 to find out, we can assume a continuing upward trend.

But satisfied as we were with the NSF report, we felt that it wasn't the whole story. A lot of what could be called *engineering research* is probably bypassed by such statistical surveys. Karl L. Fetters, in a talk before a regional meeting of the American Iron and Steel Institute, presented the same view. In discussing his own industry he pointed out that, "Today, we satisfy product demands for strengths, corrosion resistance, and many other properties that were considered impossible only a few years ago. At the same time, we have learned to produce steel from lower quality ores and coals, and to do so with greater efficiencies and speeds. . ."

"A few of the quantitative gains in the decade 1950-1960 are illustrated by the following table: blast furnace production has increased 26 pct, slag volume reduction 15 pct, beneficiated burden increased 46 pct, hot blast increase averaged 250°F, and humidified blast increased 68 pct."

"We can go on from the blast furnace to the steel plant developments. Today, we have the oxygen steelmaking processes which include the modern oxygen jets in the open hearth and the LD process in this country. The developments of these processes to their present state has been accomplished with the operating-research approach which . . . we call *practical steel plant research*".

And much of this practical plant research, whether it be in the steel plant, the brass mill, or in other metal industries, has, we are quite certain, eluded the statistician's count. The true count would show many more engineers engaged in research, at least part of the time, and would, we believe, include the majority of the members of The Metallurgical Society. FWS



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Air Separation for Steelmaking Oxygen

To meet growing competition, steelmakers are going all out to reduce production costs . . . with oxygen.

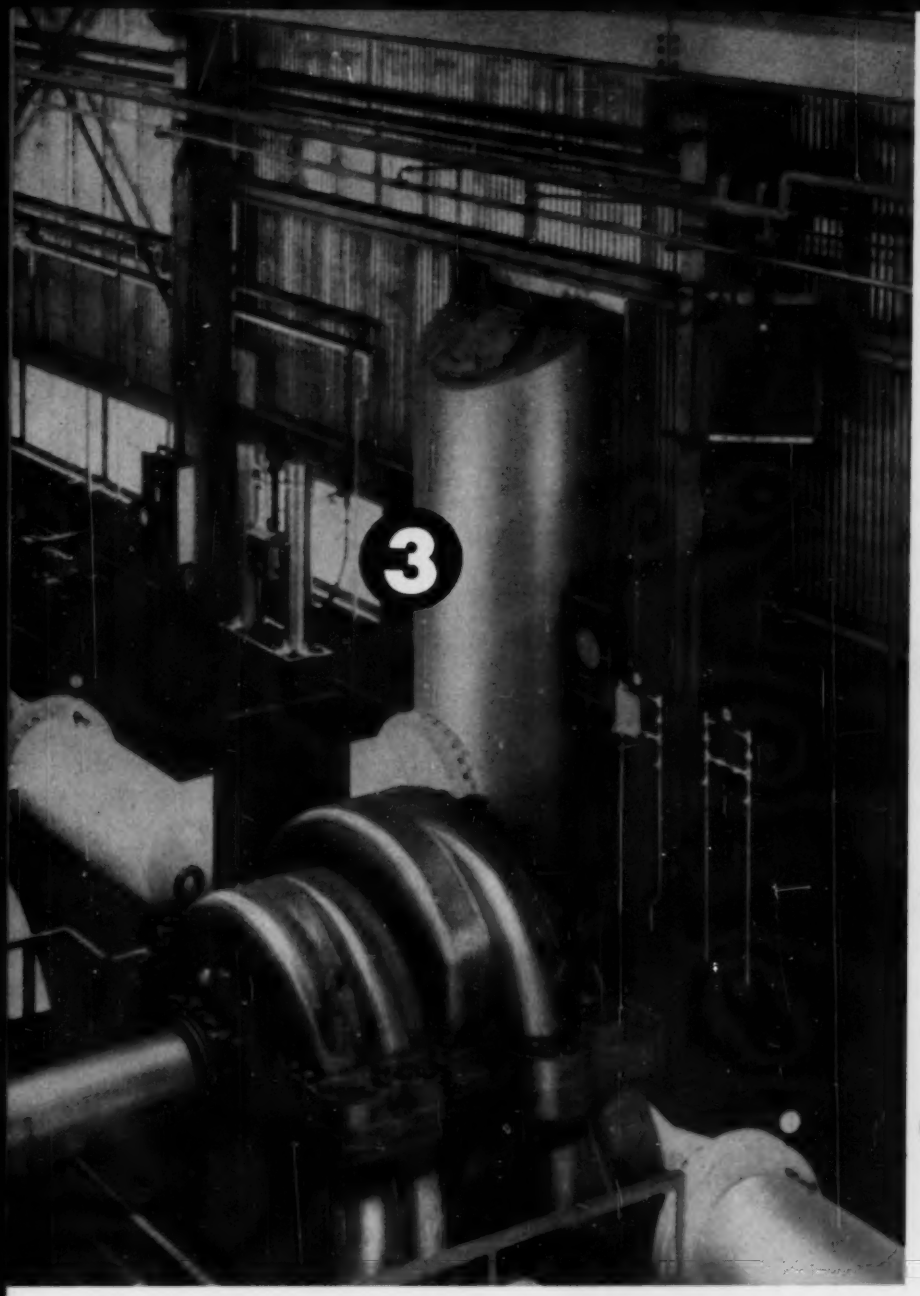
By 1965, say forecasters, new basic oxygen steel plants will be producing more than 10% of the world's steel . . . at savings as high as 30% over former methods. Open hearth producers, too, are demanding big and increasing quantities of oxygen . . . and making higher grade steels at lower costs.

Most Convenient Source . . . Air

Steelmakers are taking their oxygen from air, right at the point of use. To keep their oxygen costs per ton of steel at a minimum, many of them (or their suppliers) take advantage of the advanced design of Clark Compressors.

On the average, air separation systems using Clark Compressors require from 25 to 33⅓% less plant area than systems using other compressors of comparable output . . . with impressive savings in capital investment and in operating and maintenance costs.

Here is a specific! The two Clark *Isotemp* centrifugal compressors for handling "100-pound" air shown (3) in the foreground of the picture above require 40% less floor space than comparable machines and 50% less than compound centrifugals externally intercooled. And far less piping.



1 *Clark Non-Lube Model CRA-6 Balanced/Opposed Motor-Driven Compressor rated at 1250 bhp compresses nitrogen from atmospheric to 565 psi pressure. Vibrationless, this 14-inch stroke machine requires minimum foundation. Integrated single bundle intercoolers increase throughput and reduce bhp. Cylinder mounted intercoolers conserve space.*

2 *Four Clark-Type HS (Horizontally-Split) Centrifugal Compressors provide the Oxygen service. They are arranged in tandem with a single drive for each pair. Features of these machines include: Speed matched to drive; adjustable inlet guide vanes (for high part-load efficiency); built-in bearing alignment; up and down connections for piping economy.*

3 *Clark Isotemp "100-pound" Air Compressors. Four stage isothermal design incorporates space-saving base-mounted interstage cooling. Isolated bearing chambers at atmospheric pressure plus unique seal porting eliminates lube oil contamination of output air. (See text for space savings). Units in service all over the world. 5 to 50 thousand cfm.*

Here is another specific! In the far background of the picture (1) above is the Clark Non-Lube Model CRA-6 Balanced/Opposed reciprocating compressor that handles the nitrogen service. It's furnished as a complete space-saving package with overhung motor, intercoolers and piping. What's more, it is vibration-free and requires minimum foundation.

Much the same can be said for the four horizontally split Clark Centrifugals (2) that compress the oxygen in this plant . . . maximum throughput with minimum floor space and piping.

Expert engineering assistance anywhere in the world

If you are considering air separation to produce oxygen in quantity for steelmaking or other purposes, don't hesitate to call on Clark for help with the compression engineering. Send over-all specifications, tons per day of oxygen needed, ambient temperature, site location, type of drive (steam or electric).

A specialist from Clark will assist you quickly with preliminary equipment selections. Contact your nearest Clark office or the Overseas Division, Clark Bros. Co., 122 East 42 Street, New York 17, New York.

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Deep Drawing Conf. Planned for May 1962 In Dusseldorf, Germany

The International Deep Drawing Research Group of the Verein Deutscher Eisenhuettenleute is organizing an international symposium on developments and research with thin sheet. The symposium, which will be held in Dusseldorf, Germany on May 23-24, 1962, follows a forum organized in Paris in May 1960.

The two themes which will be considered are: 1) The influence of speed in pressing, including high-speed forming, and 2) The influence of the state of the surface in pressing, taking into account the state of the surface of the tools and the sheet, the presence of a coating, and the lubrication.

SPE Holds 36th Fall Meeting in Dallas

The Society of Petroleum Engineers of AIME held its 36th Fall Meeting in Dallas, Texas, on October 8-11. Some 2000 engineers were in attendance, including registrants from Saudi Arabia, Bahrain, Venezuela, France, and the Netherlands. Over 100 technical papers were presented at 20 sessions. The Fall Meeting included an exhibition at the Dallas Memorial Auditorium, with 70 exhibiting companies participating. Earl M. Kipp, Standard Oil Co. of California, San Francisco, is President of SPE.

In attendance were R. R. McNaughton, President of AIME; Ernest Kirkendall, General Secretary of AIME; H. N. Appleton, Assistant Secretary; C. J. Hicks, Western Field Secretary; and R. W. Shearman, Secretary of The Metallurgical Society of AIME.

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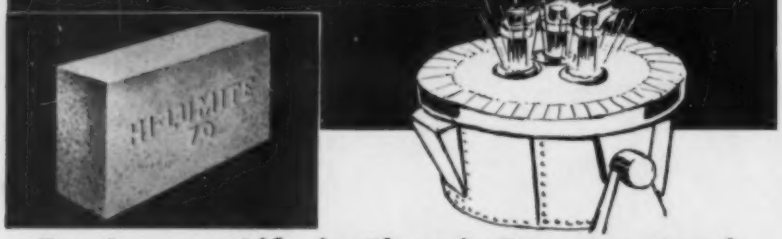

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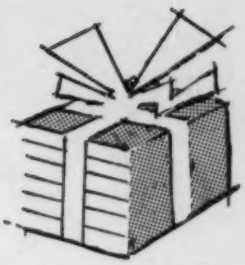

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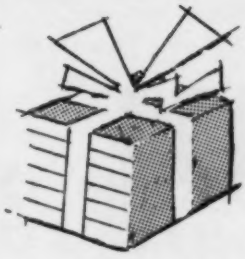

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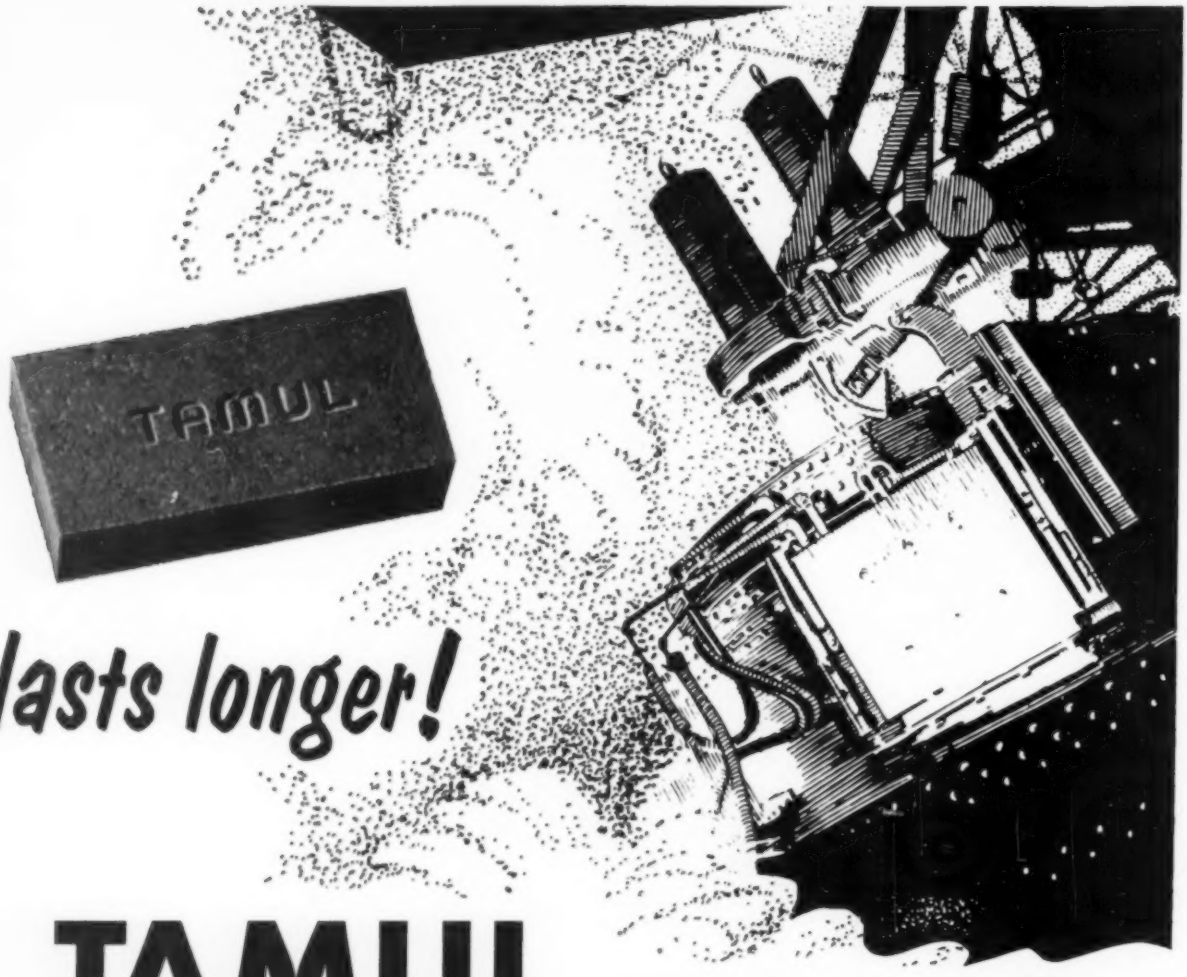

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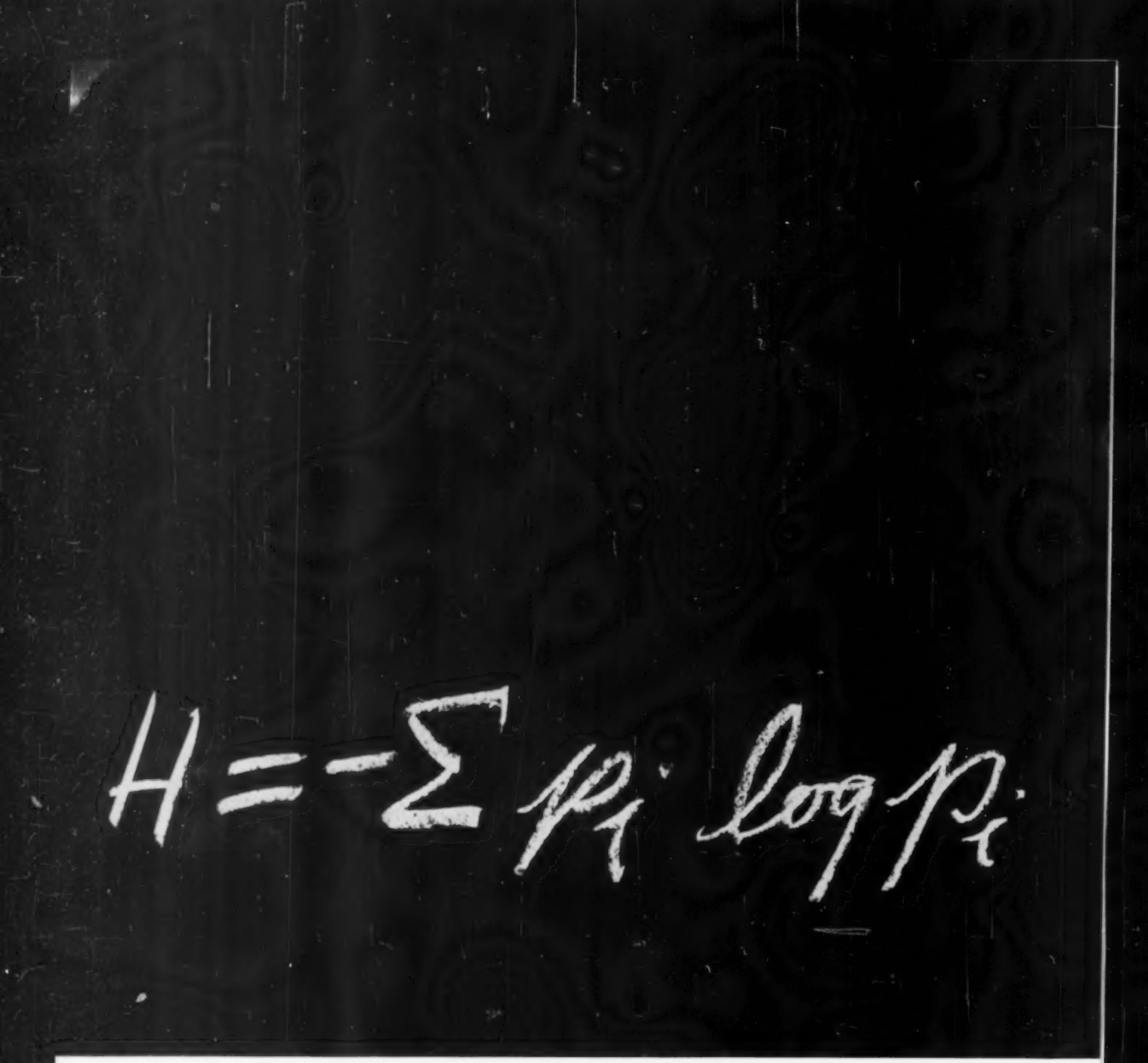

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Unlike most other elements, sulfur is always present in solid steel as non-metallic inclusions. They are complex, consisting of sulfides of iron, manganese and other elements. As a further complication, oxygen content of the steel also plays a role in sulfide formation. Thus a study of sulfur in steel is not limited to a single phase diagram, but must deal with a very complex system. Consider, too, that the high temperature sulfides, such as those of manganese, have a melting point higher than tap temperature of most steels. Others have low melting points, and crystallize during ingot solidification.

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Hot shortness—the breaking up of ingot surfaces during rolling—is largely due to the presence of iron-rich sulfides. They have a low melting point, are liquid at rolling temperatures, and form in grain boundaries. When steel is hot-worked, the surface breaks open in areas where these sulfides have become liquid and weakened the steel at grain boundaries. The only way to counteract this problem is by insuring formation of manganese sulfide inclusions which have a higher melting point, and form across grain boundaries.

Sulfur Is Added Deliberately to Steels to Improve Machinability

Sulfides provide planes of weakness along which cutting tools can move easily with less friction than in low-sulfur steels. Both type and shape of inclusion determines effectiveness of sulfur. Thin, stringer-type inclusions, or sulfides with silicate "tails", are not as effective in promoting machinability as inclusions with a globular shape.

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Foote has been searching continually for solutions to the problems associated with sulfur in steel. Foote markets a manganese sulfide alloy for steel addition which insures that all added sulfur is combined with manganese, and cannot form undesirable iron-sulfur inclusions. Foote also offers Mansulox®, an oxygen-bearing manganese-sulfur, adding needed oxygen to the heat to help formation of globular inclusions.

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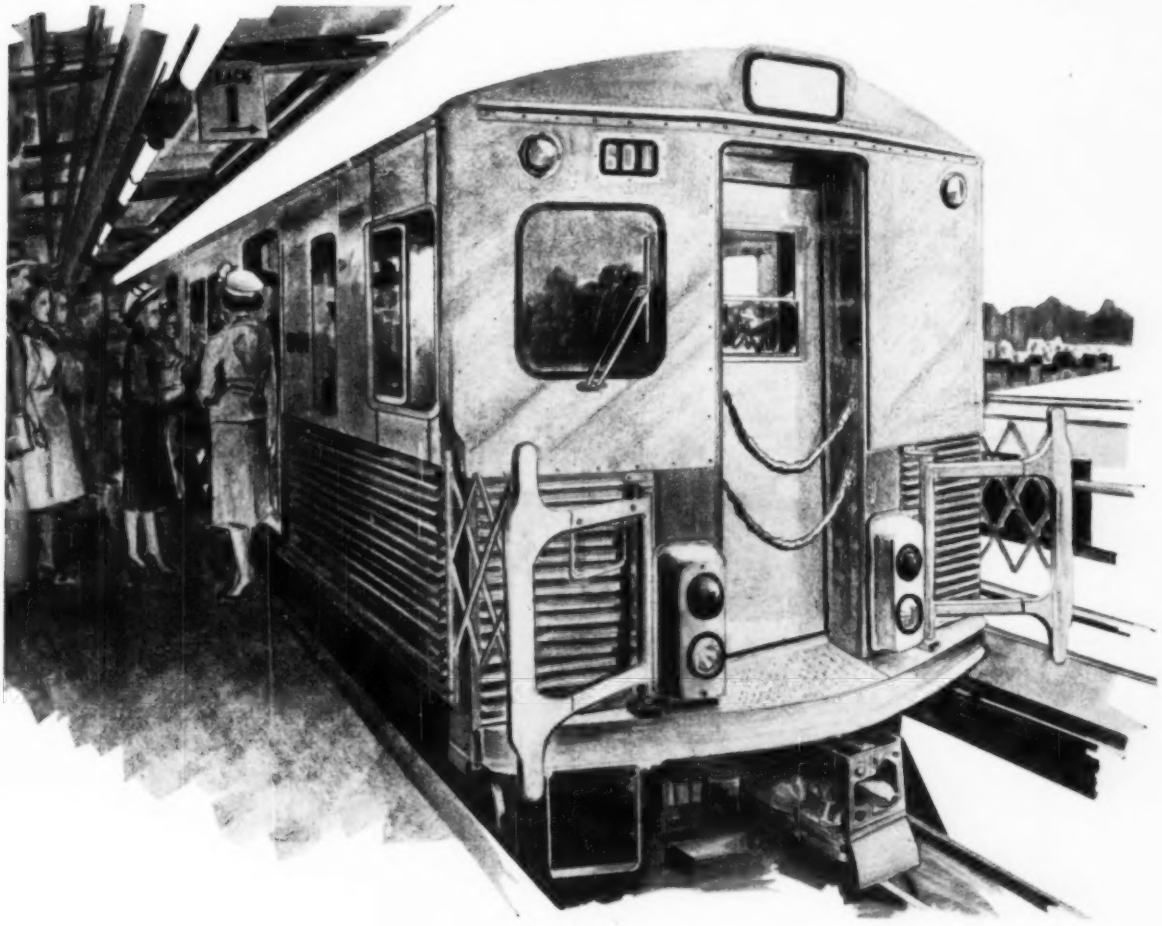

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BOOKS

(Continued from page 858)

use. The last section of the book concerns the principles of device design and descriptions of some experimental and prototype units which have been built and evaluated.

Industrial Water Treatment Practice, edited by P. Hamer, J. Jackson, and E. F. Thurston, Butterworth Inc, in association with Imperial Chemical Industries Ltd. 501 pp., $16.50, 1961. •

This book is concerned with the treatment of water for use as the raw material for steam generation and as cooling water.

For the information of its own staff, Imperial Chemical Industries prepared and circulated within the company a volume which gives an account of experience in the company's factories, together with that obtained both from advising other industrial users of water and from a critical examination of the published literature. It is this volume, suitably modified and brought up to date, which is available.

Oxidation of Tungsten, by V. D. Barth and G. W. P. Rengstorff, DMIC Report 155, 165 pp., no price quoted, 1961—This report presents a detailed review of available information on the oxidation of tungsten and its alloys. Present knowledge of tungsten oxidation is incomplete, and the state of the art has not yet reached the point where final conclusions can be drawn.

Various theories for the mechanism and rates of tungsten oxidation at different temperatures are reviewed, and the effect of pressure and water vapor on the stability of tungsten oxides is discussed in detail.

The elevated-temperature reactions of tungsten with other materials, such as refractory oxides, and with gases other than oxygen are also covered.

Some information on the protection of tungsten by alloying and coating is included; however, the subject of protective coatings is covered in more detail in another DMIC report now in preparation.

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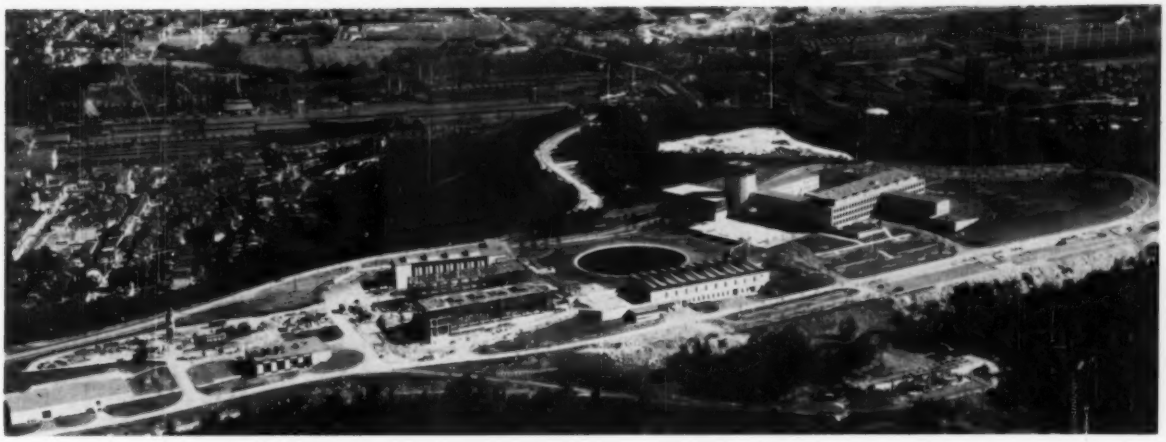

Bethlehem Steel Dedicates Homer Research Laboratories

Bethlehem Steel Co.'s $25-million Homer Research Laboratories were dedicated in October. Located on a 1000 acre site atop South Mountain, Bethlehem, Pa., the five main structures (and two under construction for Phase II) are clustered around an attractive, but functional cooling pond. The structures, all framed in structural steel and faced with Indiana limestone and random ashlar, provide a total of 475,000 sq ft of floor area; the project was designed to permit a 300 pct expansion of physical facilities. There are presently more than 450 research personnel at the laboratories which occupy about 75 acres of the mountain top site.

Projects at the new research laboratories will range from studies of involved chemical reactions to practical investigations on how to build better refractory linings.

Since Bethlehem produces an unusually wide range of steel products, the activities of these laboratories cover many technological fields, including process metallurgy, chemical engineering, physical metallurgy, mechanical engineering, ceramics, physics, corrosion engineering, chemistry, mineralogy, electronics, mechanics, thermodynamics, and nuclear studies.

Research at the new project will involve not only bench-scale work in laboratories, but also pilot manufacturing plants.

Buildings

The administration wing of the main building provides offices for engineers from all the research divisions as well as the patent, technical information, and service divisions. A lounge, library, and cafeteria for research personnel are also located in this wing.

In the laboratory wings, bench scale laboratories are provided on three floors for the physics and physical metallurgy divisions. In addition, there are bench laboratories for the chemistry, ceramics, and chemical engineering divisions.

Research activities in the shops and warehouse building include welding, structures testing, machinability, and heat treatment. There are shop facilities for sheet metal, welding, carpentry, and machine shop.

The process metallurgy building is a high-bay structure designed to house pilot-plant equipment. Included are a 3-ton electric-arc furnace, three air-induction furnaces, and a vacuum-induction furnace. A consumable-electrode furnace is planned for future installation.

There is also a Photography Building, a Central Heating and Refrigeration Building, and a cooling pond.

Under construction are the Electro-Mechanical Building which will house hot- and cold-rolling mills and equipment for research in computer-control of mill operation; and the Mechanical Engineering Building. This building, which will be used for process development work, will be equipped with a pilot line for strip process development and hydraulic press equipment.

Arthur B. Homer

The new Laboratories are named for Arthur B. Homer, Bethlehem's chairman and chief executive officer. Mr. Homer has spent his entire career with Bethlehem, joining the company in 1919. He later became vice president in charge of the shipbuilding division, president of the company, and chairman. It was through Mr. Homer's long-standing interest in all phases of steel technology that the new Bethlehem research facilities were planned, designed, and built.

Speaking at the dedication ceremonies, Mr. Homer said, "In recent years, Bethlehem has done much to improve methods and equipment for beneficiating and agglomerating iron ores for the blast furnace, such as pelletizing and sintering. . . . We have made great progress in increasing the efficiency of the open hearth by using oxygen."

Mr. Homer continued, "It is possible that 10 years from now steelmaking will largely be controlled by instruments which continuously analyze steel and slag throughout the process, and in turn automatically control the addition of scrap, pig iron, limestone, and other components that are used during refining.

"We are developing automatic control in the open hearth, because oxygen blowing of heats is cutting the refining time in half, and thus making it more difficult to shape up the slag and otherwise control the refining process."

Discussing future developments, Mr. Homer said, "We are working on a special new alloy steel which shows great promise in meeting the tremendous high-strength requirements of space vehicles.

"Processes by which metals like chromium, titanium, aluminum, and others are actually diffused into the surface layers of sheet steel are now being studied. Fundamental studies of alloy additions are under way which will cause an impervious oxide film to form on steel. Methods to combine plastic compounds and steel are being considered. Out of these broad research programs will emerge new steel products with greater durability and wider applications."

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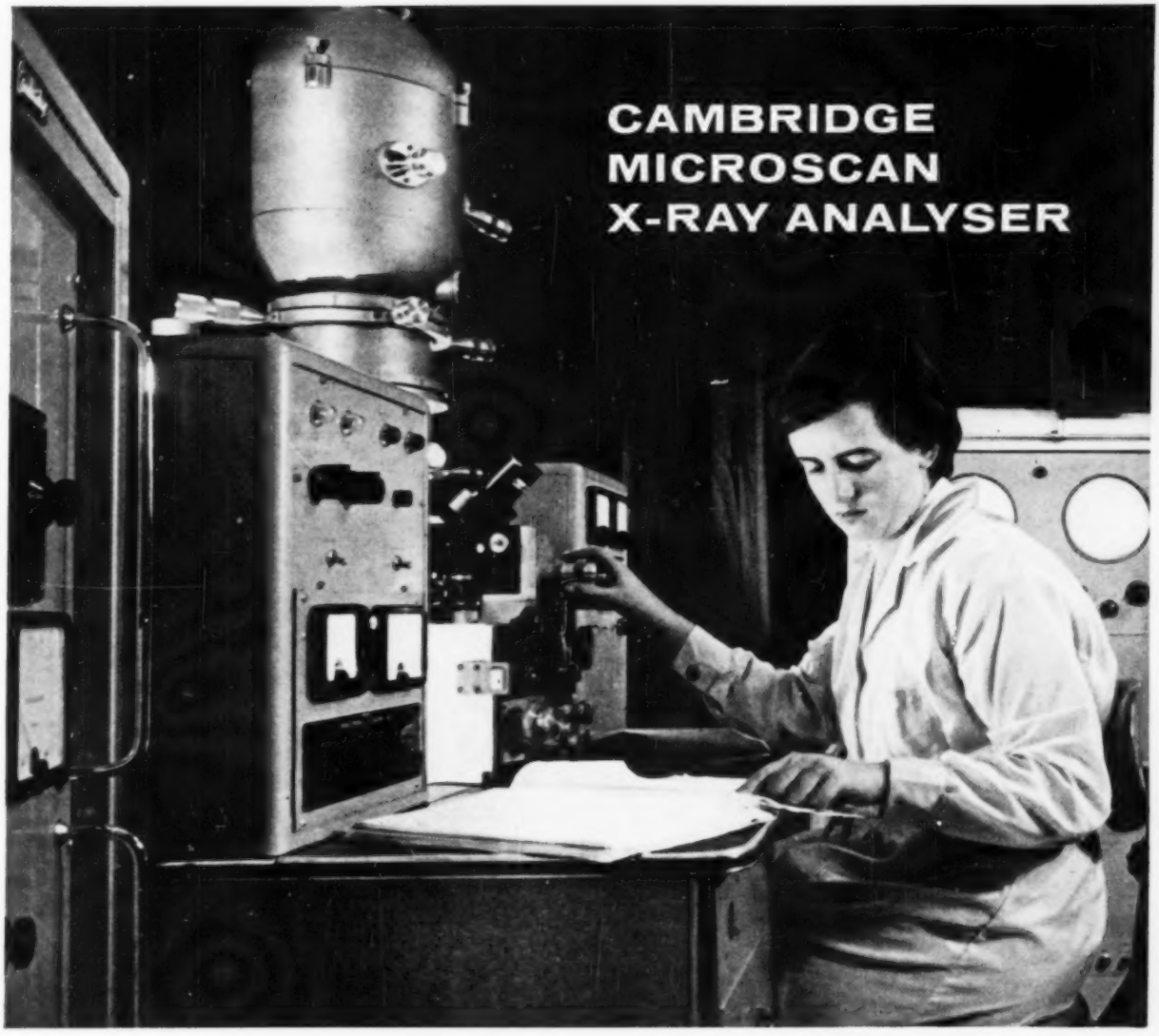

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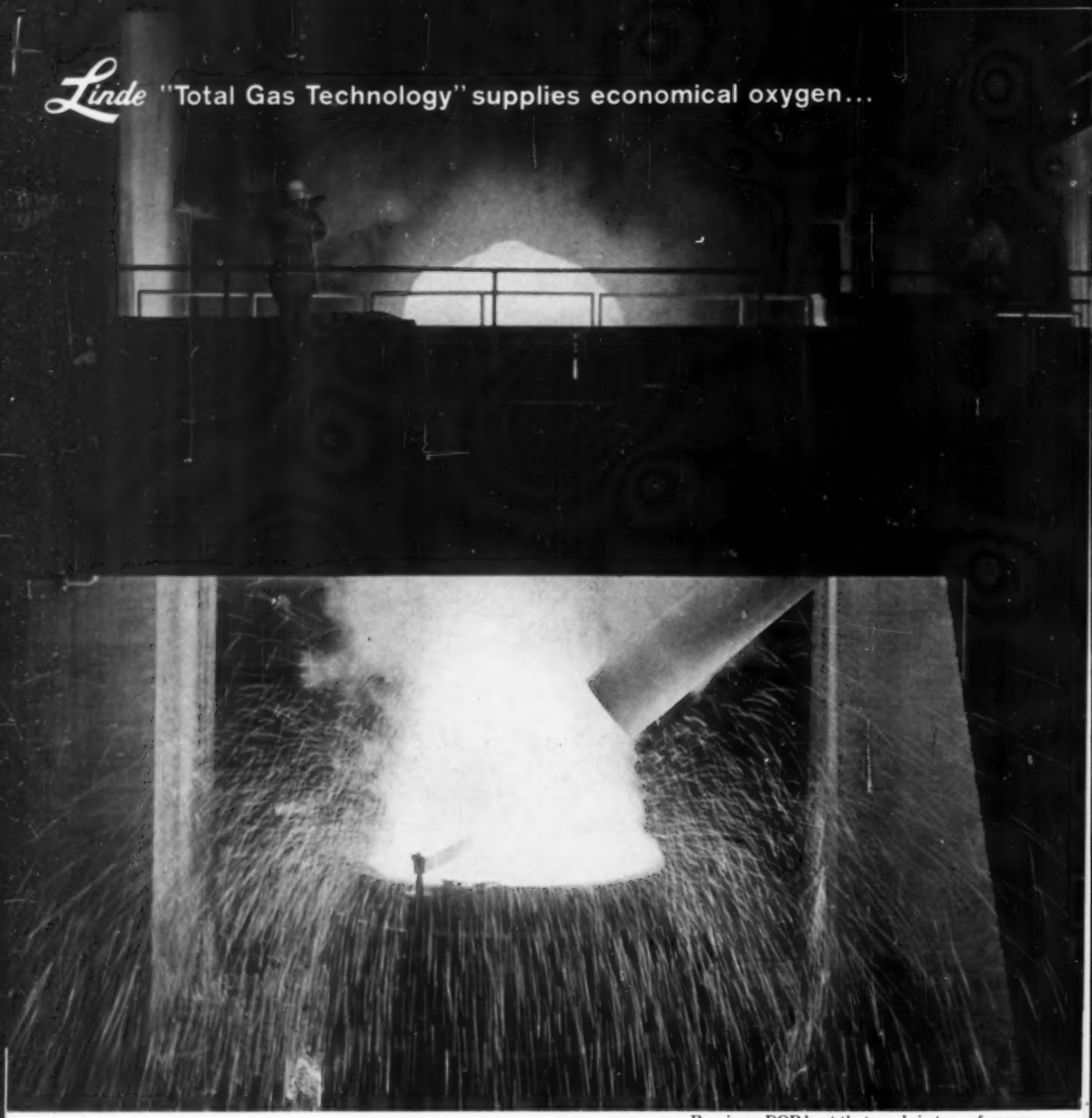

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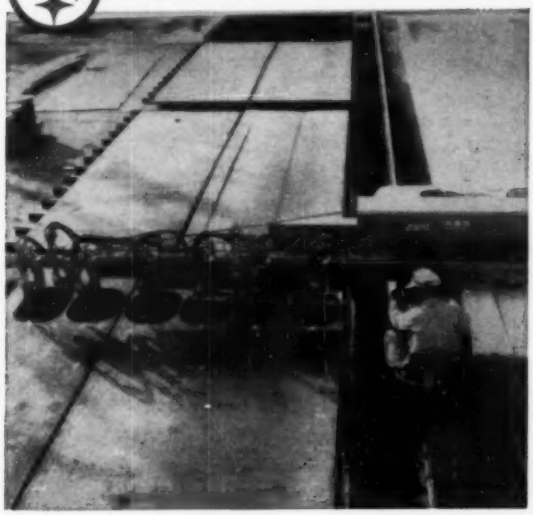
Steel costs lowered by modern technology



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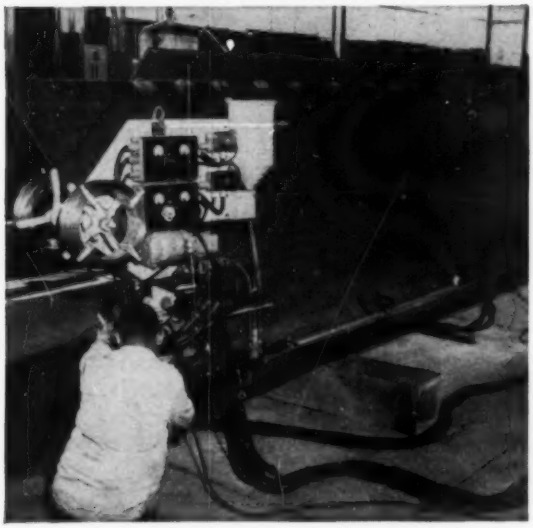

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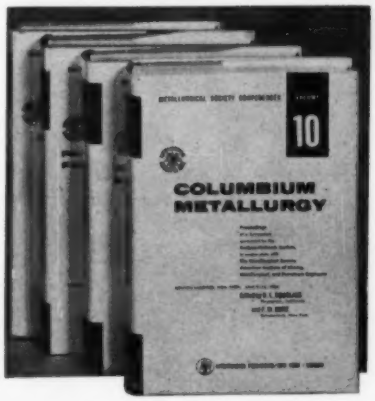

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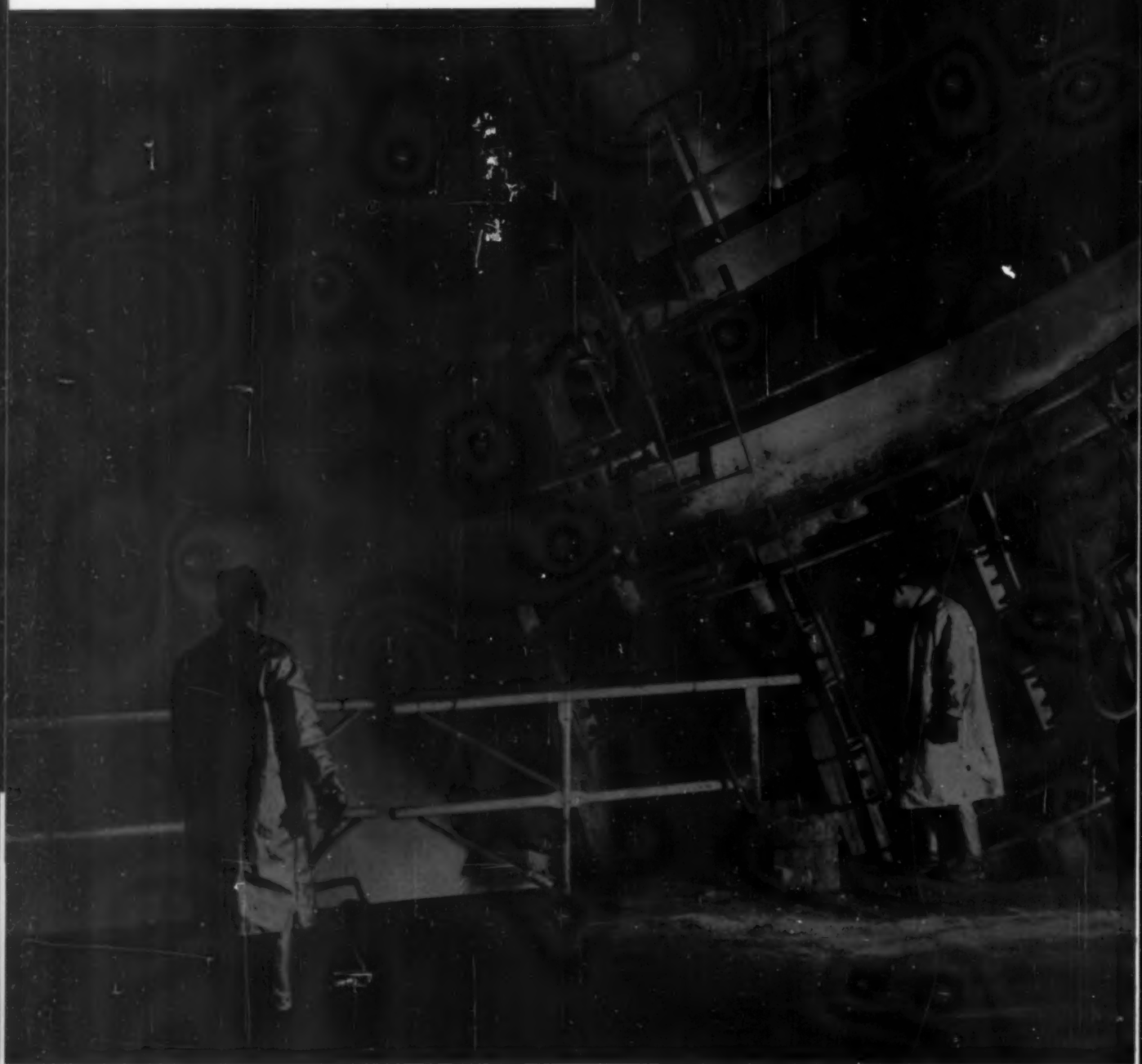

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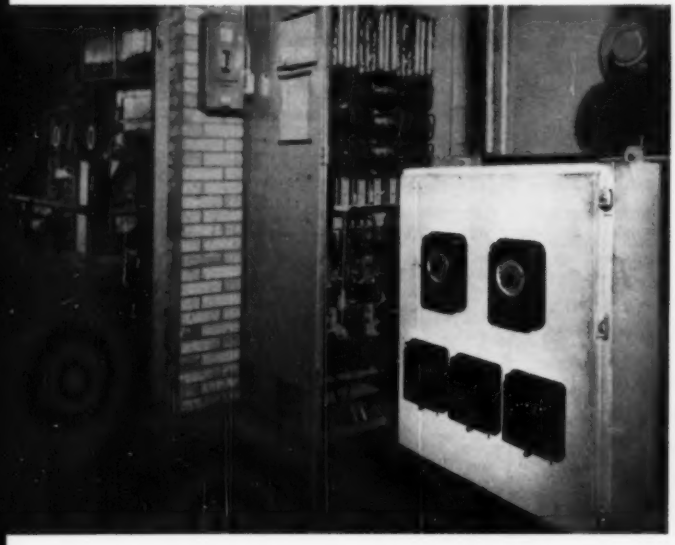

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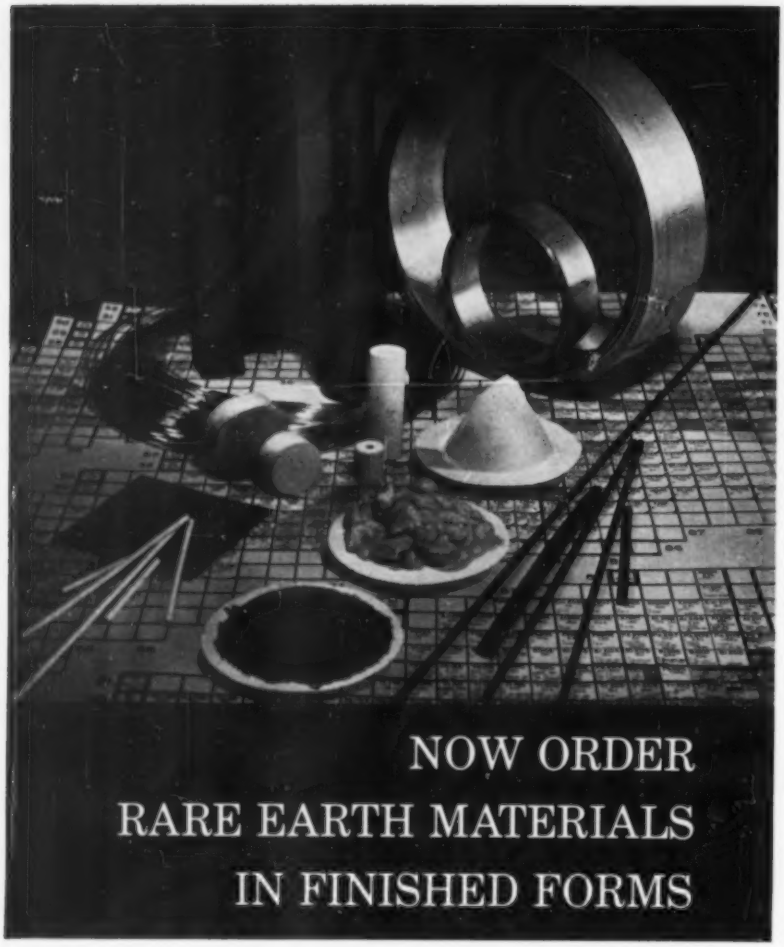

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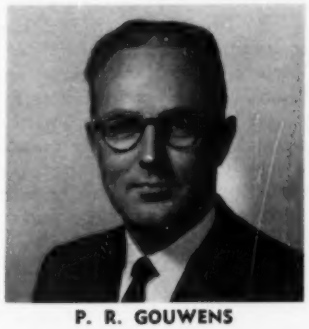
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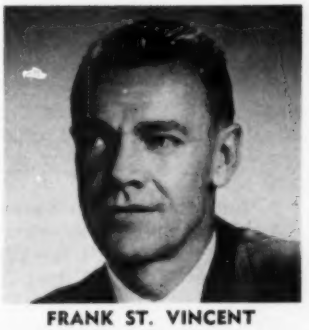
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Report of the Chairman, Electric Furnace Executive Committee

The Electric Furnace Committee has endeavored to promote the objectives of The Metallurgical Society and of the American Institute of Mining, Metallurgical, and Petroleum Engineers through careful programming and through publications. The annual conference is meant to be a neat parcel where the supplier, the production man, the plant metallurgist, and the final customer of the electric furnace product, can all obtain information of value. A plant visit is included as the concluding feature of each conference.

Conference Themes

Each Conference is built around a theme. In 1960 the theme was *Cleanliness*. Sessions bore such titles as *Nonmetallic Inclusions in Steel, Factors in Improving Steel Quality, Ferroalloy Quality and Standardization vs. Steel Quality,* and *Control of Non-Metallics in Steel for Castings.*

The Conference depends heavily on the Physical Chemistry of Steelmaking Committee. This Committee schedules one complete technical session each year that serves to relate theory to practice, and keeps the Conference abreast of the most recent advances in technology.

Publications

Publication of Proceedings volumes provides an annual record of advances in steelmaking. The technical papers presented each year reach a wider audience than the registrants alone.

In order to package the printed product more attractively, a change in type style was adopted at the time of the 1960 Conference. The most recent Proceedings are the first to use bolder and clearer type for headings and captions.

Although each annual volume contains an authors and subject index, a 15-year consolidated index was issued at the time of the 1958 Proceedings, recording all material published from 1943, the first year of the Conferences, through 1957.

The Electric Furnace Committee has worked closely with the Physical Chemistry of Steelmaking Committee in preparing a basic book on electric furnace steelmaking. The manuscripts are now with the publisher, and publication is expected in 1962. Clarence E. Sims of Battelle Memorial Institute has served as technical editor.

Scope of Committee

Several years ago the Executive Committee took cognizance of the broader use of the electric arc furnace than for steelmaking alone. In addition to producing steel for ingots or for castings, it was recognized that much of the technology was also used by makers of ferro-alloys, calcium carbide, phosphorus, refractories, and abrasives. Hence, the adoption of a third sub-committee known as the *Special Arc Group*. Hence, also the change of name from Electric Furnace *Steel* Committee to Electric Furnace Committee.

United Engineering Center

Recognition was given to the new United Engineering Center through three pledges of $1000 each from the Electric Furnace Committee in three successive years.

Establishment of Award

The Electric Furnace Committee has established an Electric Furnace Conference Award to be given for the best paper at each annual Conference. The first award will be to recognize the best paper at the 1961 Conference and will be presented at the 1962 Conference.

Secretary to South America

The Executive Committee responded to an invitation from the Latin American Iron and Steel Institute to send an *Invited Observer* from AIME to its first Annual Congress in Sao Paulo, Brazil, in May 1961. The Executive Committee agreed to pay the expenses of its Secretary, Robert W. Shearman, for the Congress, and for an extended trip to integrated steel plants throughout South America.

It is believed that the broadened outlook will result in more papers for future conferences and for additional technical material for JOURNAL OF METALS.

Death of Past Chairman

All members of the Electric Furnace Committee were saddened by the sudden death of Albert C. Ogan, recent Past Chairman. Mr. Ogan gave strong leadership to the Conferences, and continued his participation in Conference planning through service on ad hoc committees. At the time of his death, Mr. Ogan was assistant division superintendent, steel production, Duquesne works, U.S. Steel Corp., Duquesne, Pa.

Summary

The Executive Committee has consistently endeavored to maintain a unity of purpose in its programming and publications. The prime objective of the Electric Furnace Conferences is to present material of scientific and technical value to all associated with the electric arc furnace process.

GEORGE C. OLSON
Works Manager
Atlas Steels Ltd.
Welland, Ontario

19th Annual Electric Furnace Program

Sponsored by the Electric Furnace Committee of the Iron and Steel Division, The Metallurgical Society of The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc.

Penn-Sheraton Hotel, Pittsburgh — December 6-8, 1961

REGISTRATION

Tuesday, December 5—3:00 to 9:00 pm.
Wednesday, Thursday, and Friday, December 6-8—8:30 am to 5:00 pm—Fort Duquesne Room

TUESDAY, DECEMBER 5

5:00 pm—Room 566

Business Meeting:
Electric Furnace Committees Annual Dinner and Business Meeting.

WEDNESDAY, DECEMBER 6

Authors and Chairmen Breakfast: 8:00 am—Sky Room. Authors and session chairmen will meet for breakfast followed by an opportunity to plan final details with regard to the scheduling of papers for each session.

Joint Technical Session

WEDNESDAY, DECEMBER 6

9:30 to 9:45 am—Ballroom

General Session

Welcoming Remarks:
By C. G. Mickelson, Chairman, Committee for the Nineteenth Annual Conference.

Response:
By G. C. Olson, Chairman, Electric Furnace Executive Committee—Announcements and Reports.

9:45 am to 12:30 pm—Ballroom

Use of Vacuum and Inert Gas Atmospheres in Steelmaking

(Arranged by Physical Chemistry of Steelmaking Committee)

Chairmen:

Hyman Freeman, Superintendent, Quality Control, Universal Cyclops Steel Corp., Bridgeville, Pa.
H. O. Beaver, Assistant General Superintendent, The Carpenter Steel Co., Reading, Pa.

1. **Current and Potential Use of Vacuum and Inert Atmosphere Fabrication Processes:**
Paper by P. C. Rossin, General Manager, and C. P. Mueller, Universal-Cyclops Steel Corp., Bridgeville, Pa.

2. **The Dortmund-Hoerder (Alloying and Degassing) Process:**
Paper by C. D. Preusch, Manager Technical Development Technology Department, and W. C. Kollman, Superintendent of Melting, Midland Works, Crucible Steel Co. of America, Pittsburgh, Pa.

3. **Production of Large Ingots by Consumable Electrode Melting:**
Paper by W. W. Dyrkacz, Manager of Quality Control, Allegheny Ludlum Steel Corp., Watervliet, N. Y.

Ingot Technical Session

2:00 to 5:00 pm—Ballroom

Operating Metallurgy

Chairman:

B. H. Brown, Supervisor of Melting, Jessop Steel Co., Washington, Pa.

Discussion Leader:

G. G. Zipf, Steel Plant Superintendent, The Babcock and Wilcox Co., Beaver Falls, Pa.

1. **Roping in the 400-Series Stainless Steels:**
Paper by H. P. Rossbach, Manager, Metallurgical Service Division, Union Carbide Metals Co., Cleveland, Ohio.
Discussion: P. B. Dennis, Manager, Mill Metallurgy, Atlas Steels, Ltd., Welland, Ontario, Canada.

2. **Segregation in Ingots:**
Paper by J. G. Mravec, Melt Shop Metallurgist, Timken Roller Bearing Co., Canton, Ohio.

3. **Lateral Segregation of Non-Metallics in Steel Ingots:**
Paper by F. F. Franklin, District Manager, Vanadium Corp. of America, Cleveland, Ohio.

4. **Calculation of Oxygen Contents in Molten Stainless Steels:**
Paper by R. A. Walsh and S. Ramachandran, Research Metallurgists, and J. C. Fulton, Chief Research Metallurgist, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

Castings Technical Session

2:00 to 5:00 pm—Urban Room

Quality Improvements in Stainless Steel

Chairman:

A. F. Gross, Research Metallurgist, The Ohio Steel Foundry Co., Springfield, Ohio.

Discussion Leader:

C. W. Briggs, Technical and Research Director, Steel Founders Society of America, Cleveland, Ohio

1. **Melting of 18-8 Stainless Steel:**
Paper by S. E. Wolosin, Superintendent, Melting, Lebanon Steel Foundries, Lebanon, Pa.

2. **Melting and Deoxidation of 12.00 Per Cent Chromium Steel:**
Paper by F. B. Riggan, Chief Metallurgist, S. W. House, Melting Superintendent, and R. E. Gray, Assistant Melting Superintendent, Texas Steel Co., Fort Worth, Texas.

3. **Grain Refinement of 17-4 Steel by Inoculation:**
Paper by J. Fuqua, Works Manager, Cooper Alloy Corp., Hillside, N. J.

Special Arc Technical Session

WEDNESDAY, DECEMBER 6

2:00 to 5:00 pm—Monongahela Room

Calcium Carbide and Phosphorus

Chairman:

D. E. Stingel, Works Manager, Union Carbide Metals Co., New York, N. Y.

Discussion Leader:

Arturo Chavez J., Production Superintendent, Electric Reduction Co. of Canada, Ltd., Varennes, Quebec, Canada.

1. **Comparative Value of Soderberg vs. Pre-Baked Electrodes:**
Paper by R. P. Van Ness, Operating Manager, Carbide Plants, Air Reduction Chemical and Carbide Co., Calvert City, Ky.
Discussion: J. A. Colquhoun, Superintendent, Carbide Division, Shawinigan Chemicals Ltd., Shawinigan, Quebec, Canada.

2. **Effects of Impurities on the Production and Reactivity of Calcium Carbide:**
Paper by J. A. Perez, Superintendent, Union Carbide Metals Co., Ashtabula, Ohio.

3. **Maintenance for Furnace Electrical System Reliability in an Elemental Phosphorus Plant:**
Paper by D. E. Bone, Maintenance Superintendent, Westvaco Mineral Products Division, Food Machinery and Chemical Corp., Pocatello, Idaho.
Discussion: H. W. Kopp, Works Manager, Columbia Plant, Hooker Chemical Corp., Columbia, Tenn.

Ingot Technical Session

THURSDAY, DECEMBER 7

9:30 am to 12:30 pm—Ballroom

Electric Furnace Practices

Chairman:

J. M. Ford, Superintendent, Midvale-Heppenstall Co., Philadelphia, Pa.

Discussion Leader:

R. W. Farley, Director, Process Development, Republic Steel Corp., Chicago, Ill.

1. **Improving the Hot Workability of Stainless Steel Containing Lead and Tin:**
Paper by D. W. P. Lynch, Project Engineer, Technical Department, Vanadium Corp. of America, Cambridge, Ohio.

2. **Effect of Tin in Types 302, 410, and 430 Stainless Steel:**
Paper by E. C. Rudolphy, Assistant Chief Metallurgist, South Works, U.S. Steel Corp., Chicago, Illinois.

3. **Oxygen Practice at Midvale-Heppenstall:**
Paper by G. W. Reese, Assistant Superintendent, Melting, Midvale-Heppenstall Co., Midvale, Pa.

4. **Oxygen as an Aid to Electric Furnace Economics:**
Paper by J. J. Wyandt, Superintendent No. 2 Melt Shop, Republic Steel Corp., Canton, Ohio.

5. **Recent Production Rates and Costs in Large Electric Furnaces:**
Paper by Ralph Wood, Assistant Superintendent, Steel Production, Sheffield Steel Div., Armco Steel Corp., Kansas City, Mo.

6. **Automatic Power Control Unit for Electric Furnaces:**
Paper by Frank Nicholson, Manager, Arc Furnace Department, Swindell-Dressler Corp., Pittsburgh, Pa.
Discussion: F. I. Marshall, Assistant Steel Plant Superintendent, Babcock and Wilcox Co., Beaver Falls, Pa.

ANNUAL DINNER

Thursday, December 7

6:30 pm—Urban Room—Reception and Cocktail Party for dinner guests.

7:00 pm—Ballroom—Dinner

Toastmaster: Frank Rackley, President, Jessop Steel Company, Washington, Pennsylvania

Speaker: Kenneth McFarland, Consultant, General Motors Corporation, Detroit, Michigan.

Castings Technical Session

THURSDAY, DECEMBER 7

9:30 am to 12:30 pm—Urban Room

Refractories

Chairman:

S. E. Wolosin, Superintendent, Melting, Lebanon Steel Foundry, Lebanon, Pa.

Discussion Leader:

A. J. Kiesler, Research Associate, General Electric Co., Schenectady, N. Y.

1. **Metal Refractory Reactions in Cast Steel and Their Relation to Formation of Macro Inclusions:**
   Paper by R. A. Flinn, Professor of Metallurgical Engineering, and L. H. Van Vlack, Professor of Metallurgical Engineering, University of Michigan, Ann Arbor, Mich.

2. **Foundry Ladle Refractories for High-Temperature Alloys:**
   Paper by K. C. Lowstetter, Division Metallurgist, Electro-Alloys Division, American Brake Shoe Co., Elyria, Ohio.

3. **Refractory Gun Practice at National Castings Company:**
   Paper by D. A. Finch, Melting Superintendent, National Castings Co., Melrose Park, Ill.
   Discussion: F. W. Younkin, Chief Metallurgist, Fort Pitt Steel Castings Division, McKeesport, Pa.
   Discussion: J. M. Hathaway, Chief Process Engineer, The Massillon Steel Castings Co., Massillon, Ohio.

4. **Current and Future Developments in Basic Refractories:**
   Paper by R. E. Pardee, Manager, Technical Services, Kaiser Refractories Chemical Division, Kaiser Aluminum and Chemical Corp., Mexico, Mo.

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Special Arc Technical Session

THURSDAY, DECEMBER 7

9:30 am to 12:30 pm—Monongahela Room

Ferro Alloys I

Chairman:

H. W. Bronson, Manganese Product Manager, Union Carbide Metals Co., Niagara Falls, N. Y.

Discussion Leader:

M. J. Geigel, Chief Metallurgist, Chromium Mining and Smelting Corp., Memphis, Tenn.

1. **Production of Standard Ferromanganese in Blast Furnace:**
   Paper by R. Flanagan, Superintendent Blast Furnace, J. M. Stapleton, R. L. Stephenson, and D. A. Fletcher, U.S. Steel Corp., Duquesne, Pa.
   Discussion: Herbert Fredrickson, Assistant Superintendent, Blast Furnace, C. J. Lavino and Company, Lynchburg, Va.

2. **Manufacture of Standard Ferromanganese in Electric Furnace:**
   Paper by Roger McLure, General Superintendent, Tennessee Products Corp., Rockwood, Tenn.
   Discussion: J. H. Lowes, General Manager of Production, Ohio Ferro Alloys Corp., Canton, Ohio.

3. **Production of Silicomanganese:**
   Paper by John Oxaal, Assistant to Superintendent, Union Carbide Metals Co., Alloy, West Va.
   Discussion: C. A. Schulte, Plant Manager, Vancoram Plant, Vanadium Corp. of America, Steubenville, Ohio

4. **Effect of Temperature on the Carbon Content of High-Silicon Alloys:**
   Paper by W. E. Anable, Metallurgist, and L. H. Banning, Project Coordinator U.S. Bureau of Mines, Albany, Oreg.
   Discussion: George Viens, Canadian Department of Mines and Technical Surveys, Ottawa, Ontario, Canada.

The Metallurgical Society of AIME

345 East 47th Street

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Gentlemen:

I am interested in joining the Society. Please send further information and an application for membership.

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Ingot Technical Session

THURSDAY, DECEMBER 7

2:00 to 5:00 pm—Ballroom

International Developments

Chairman:

W. B. Wallis, Consulting Engineer, Strategic Materials Corp., New York, N. Y.

Discussion Leader:

D. L. Clark, Melting Superintendent, Simonds Saw and Steel Co., Lockport, N. Y.

1. **Pre-Refining Process for Steelmaking:**
   Paper by Emrys Davies, Managing Director, Brymbo Steel Works, Branch of G. K. N. Steel Co., Ltd., Wrexham, Wales.
2. **Development of the Electric Furnace Industry in Japan:**
   Paper by Tatsuo Hayashi, Managing Director, Daido Steel Co., Ltd., Nagoya, Japan.
3. **Ruhrstahl Heraeus Vacuum Flow Degassing Process for Commercial Production of Alloyed and Unalloyed Electric and Open Hearth Steels:**
   Paper by Herman Maas, Ruhrstahl AG, Henrichshuette, Hattingen-Ruhr, West Germany.
4. **Development of a New Steelmaking Process:**
   Paper by J. D. Madaras, Vice President, Arkota Steel Co., Coolidge, Ariz.

Castings Technical Session

THURSDAY, DECEMBER 7

2:00 to 5:00 pm—Urban Room

Effect and Control of Metal Temperature

Chairman:

N. H. Keyser, Metallurgist, Battelle Memorial Institute, Columbus, Ohio.

Discussion Leader:

A. B. Steck, Director of Operations, Research and Systems, West Michigan Steel Foundry Co., Muskegon, Mich.

1. **Effect of Deoxidizers on Gas Content of 0.45 Per Cent Carbon and Low-Alloy Steels at Various Temperatures:**
   Paper by M. J. Boris, Senior Research Chemist, Manufacturing Research Laboratory, American Steel Foundries, East Chicago, Ind.
   Discussion: John Zotos, Assistant Professor of Mechanical Engineering, Northeastern University, Boston, Mass.
2. **Effect of Pouring Temperature on Casting and Mechanical Properties:**
   Paper by George D. Haley, Technical Manager, and G. J. Grott, Operations Manager, WaiMet Alloys Co., Dearborn, Mich.
   Discussion: C. A. Faist, Chief Metallurgist, Burnside Steel Castings Co., Chicago 19, Ill.
3. **Ladle Temperature Loss:**
   Paper by J. G. Henzel, Jr., Applied Research Engineer, and J. Keverian, Manager, Applied Research and Development Laboratory, General Electric Co., Schenectady, N. Y.
4. **Trends in Temperature Measurement of Open Hearth and Electric Furnace Molten Iron and Steel:**
   Paper by C. R. Bingham, Senior Application Engineer, Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.

• Wear Your Meeting Badge to Technical Sessions •

HISTORY OF IRON AND STEELMAKING IN THE UNITED STATES

A "History of Iron and Steelmaking in the United States" contains a wealth of information on early colonial charcoal furnaces, beehive to modern coke ovens, the age of bessemer steelmaking through open hearth and electric furnaces, and the history of ferro-alloy manufacturing. All of the 13 chapters have appeared in JOURNAL OF METALS, and have been written by experts in their fields.

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Special Arc Technical Session

THURSDAY, DECEMBER 7

2:00 to 5:00 pm—Monongahela Room

Ferro Alloys II

Chairman:

H. C. Parkman, Assistant Vice President, Operations, Vanadium Corp. of America, Cambridge, Ohio.

Discussion Leader:

K. W. Cunningham, Vice President, Operations, Ohio Ferro Alloys Corp., Canton, Ohio.

1. **Use of Waste Molten Slag to Increase Ladle Refractory Life:**
   Paper by A. D. Gate, Technical Director, Interlake Iron Corporation, Beverly, Ohio.
   Discussion: D. E. Halter, Chief Metallurgist, and F. P. Souders, General Foreman, Hanna Nickel Smelting Co., Riddle, Oregon.

2. **A Study of Hydrogen in 50 per cent Ferro-Silicon:**
   Paper by T. W. Merrill, Director of Product Research, Vanadium Corp. of America, Cambridge, Ohio.
   Discussion: E. R. Saunders, Manager Quality Control, Union Carbide Metals Co., Cleveland, Ohio.

3. **Construction and Operation of Pilot Plant to Produce Ferrochrome from Montana Chromite Concentrates:**
   Paper by M. E. Hertel, Superintendent of Melting, American Chrome Co., Nye, Montana.
   Discussion: M. L. Wamstad, Assistant Plant Superintendent, Pittsburgh Metallurgical Co., Calvert City, Ky.

Plant Trip

FRIDAY, DECEMBER 8

Plant Trip

Chartered Buses will leave from the Penn-Sheraton Hotel in the morning.

There is a choice of visiting either the Jessop Steel Company, Washington, Pa., or the McConway and Torley Company, Pittsburgh.

The trip to the Jessop Steel Company will include the Ingot Shop. Chartered Buses will leave from the Penn-Sheraton Hotel at 9:15 a.m., and return to Pittsburgh at 3:15 p.m. Lunch will be provided, courtesy of Jessop Steel Company. A charge of $2.00 is being made for the plant trip to cover the cost of transportation.

The trip to McConway-Torley will feature an inspection of the Casting Shop. Chartered buses will leave from the Penn-Sheraton Hotel at 9:45 a.m. and return to the Hotel at 11:45 a.m. The charge for transportation will be $1.00.

Cameras will not be permitted in either plant.

General Information

Registration: The registration desk will be in the Duquesne Room of the Penn-Sheraton Hotel, on Tuesday, December 5, from 3:00 pm to 9:00 pm, and Wednesday, December 6, through Friday, December 8, from 8:30 am to 5:00 pm. The registration fee for the Conference is $12.00, which includes a copy of the Proceedings when printed. There is no registration fee for students at any of the sessions, unless they desire a copy of the Proceedings. AIME members are entitled to a $4.00 reduction in the registration fee. Your badge admits you to all sessions. Registration is not required to attend the Annual Dinner.

Of your registration fee at this Conference, $10.00 is applicable on your AIME entrance fee when applying for full or associate membership, until March 31, 1962.

Discussion at Technical Sessions: All technical sessions will be held at the Penn-Sheraton Hotel.

The program is arranged so that there will be ample time for oral discussion of all topics. Delegates are invited to ask questions or to contribute to the Proceedings by giving the others in attendance the benefit of their experience. Each oral discussion is limited to five minutes; discussions longer than this should be written for publication in full in the Proceedings and should be summarized in the oral presentation.

Any delegate who desires to discuss any of the subjects brought before the Conference and who does not want his discussion published should so inform the Chairman before he begins to talk, or immediately after he has finished, so that it can be deleted by the recording stenographer. A transcript of all recorded remarks is returned to the discusser immediately after the meeting for approval or for editing before publication in the Proceedings.

Buy Dinner Tickets in Advance: It is imperative that the Local Committee and the hotel know well in advance the number to be served at the annual dinner on Thursday evening. Please purchase dinner tickets (price $10.00; gratuities included) before noon Thursday. All tickets will be reserved and assigned to tables in the order received. If you wish to sit with someone, please purchase tickets simultaneously by mail or in person. Dinner tickets admit the holder to the cocktail party given at 6:30 pm.

Past Registrants of the

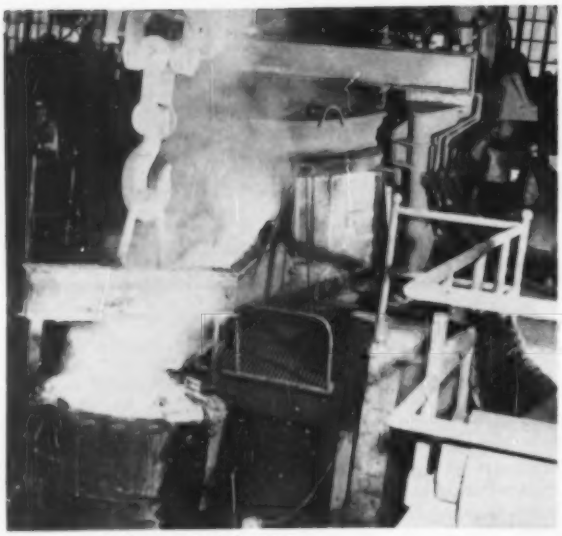
Electric Furnace Conference, AIME

You are entitled to purchase, at this time and at the special rate, the following available volumes of the Proceedings of the Electric Furnace Conferences at $7.00 per volume ($10.00 to non-registrants)

Volume 18 (1960)	Volume 14 (1956)
Volume 17 (1959)	Volume 7 (1949)
Volume 16 (1958)	Volume 6 (1948)
Volume 15 (1957)	Volume 5 (1947)

PLANT TRIPS

As a part of the Nineteenth Annual Conference of the Electric Furnace Committee, plant trips are planned to Jessop Steel Co., Washington, Pa., and to McConway & Torley, Pittsburgh. This is a preview of these visits.



McConway & Torley's 6-tph furnace

I. McConway & Torley

by Donald Y. Clem

Jessop's Washington, Pa. plant

Less than three years after Sir Henry Bessemer inaugurated the steel epoch in 1866 with announcement of his converter, William McConway and John Torley opened their foundry on the bank of the Allegheny River in Pittsburgh.

They began their pioneering early. At that time, locomotives and freight and passenger cars on the world's railways were coupled with simple link-and-pin draw bars. This method of coupling was inefficient and extremely dangerous. Working with Eli Janney, an inventor, McConway and Torley developed a knuckle-type coupler—the first automatic coupler to be approved by the Master Car Builders Assn. and the forerunner of the present AAR standard coupler now used on all railways in the United States.

During the same year that McConway and Torley brought out their revolutionary coupler, they changed from a partnership to a corporation. The corporation grew and expanded until it became one of the large producers of castings for industry and railways throughout the world.

Steelmaking facilities at McConway & Torley Corp. consist of two Pittsburgh Lectromelt electric arc furnaces, designed for top charging and acid practice. The smaller furnace, rated at 3 tph, is powered by a 2800-kva transformer; this furnace is used only as a stand-by for emergency. The more-efficient, larger furnace, rated at 6 tph, is powered by a 5000-kva transformer. These ratings are somewhat ambiguous, since the current average heats on the larger furnace are 15 tons with an average charge-to-tap time of 2 hr 7 min. The furnaces are silica-brick lined with shaped silica blocks forming the roof. The recent average life of the furnace lining was 325 heats, with the roof life slightly less—approximately 300 heats.

The furnaces are charged with selected scrap, low in phosphorous and sulfur. Approximately 30 pct of the charge is usually made of foundry returns, such as gates and risers. All heats are carbon steel and low-alloy steel, with AAR grade *B* and grade *C* steels under AAR specification M-201 comprising the great majority.

Within the past few years, the use of injected oxygen has been introduced and adopted into standard practice as the principal oxidizing medium for all grades of steel produced. Experiments are being made to speed the rate of melt-down by the use of burners utilizing gas and oxygen, but the results are inconclusive thus far.

Foundry facilities are mechanized for machine molding on a production-line basis. In addition, a large area is maintained for floor molding as well as a recently-constructed 20 x 20-ft pit for larger castings. A battery of 14 batch-type heat-treating furnaces and three car-bottom furnaces are available for heat treatment. During the past six months, a 72-cu-ft Pangborn Roto Blast Machine was installed in the cleaning and finishing dept. with complete mechanized material handling equipment.

McConway & Torley Corp. is producing and marketing AAR, type *E*, freight car couplers of cast high-tensile steel. This nickel-chrome-moly alloy steel was developed by McConway & Torley Corp. In addition to its high tensile and high yield characteristics, this steel enables couplers to withstand impact and remain operational under severe climatic conditions.

Today, McConway & Torley Corp., a subsidiary of the Ellicott Machine Corp. of Baltimore, Md., is one of the most modern and up-to-date foundries, able to produce carbon and alloy steel castings on a production or jobbing basis from 50 to 20,000 lb.

DONALD Y. CLEM is executive vice president of McConway & Torley Corp., Pittsburgh, Pa.

II. Jessop Steel

by F. K. Noll and H. K. Taylor

Jessop Steel Co. of Washington, Pa., one of the most highly-specialized, integrated steel plants in the United States, is one of the oldest steel companies in the world. It had its beginning in Sheffield, England, in 1774—before the Revolutionary War when it was known as Wm. Jessop & Sons Ltd.

In the latter part of the 19th Century demand for Jessop's specialty steels in this country was so great that construction of the Jessop mill in Washington was undertaken. The plant was completed in 1901, and the firm became a still more important supplier of specialty steels to the booming industrial revolution taking shape in this country.

Jessop built its reputation in this country primarily as a supplier of tool steels and saw steels. The new subsidiary plant in Washington continued to supply these items and branched out in other specialty steel fields. In 1924 Jessop's facilities in the United States were bought out by local interests.

Specialty steels, such as those made by Jessop, are used in an ever-widening spectrum of commercial and defense applications. These include heat, corrosion, abrasion, and shock resistant steels; non-magnetic steels; precision ground steels; high-speed tool steels; cast-to-shape steels; aircraft and commercial quality alloy steels; saw steels; clad steels; and many others. Also, Jessop helped develop stainless steels containing boron additives for defense applications. And at Jessop rare earth minerals, such as lanthanum and cerium, are used in the steelmaking process for advantages in workability.

In recent years a significant development in the Company's history was the formation of a nationwide warehousing division with headquarters in Chicago. In establishing this Service Centers Div., Jessop moved for the first time beyond the specialty and alloy-producing fields. Behind the move was a careful, year-long study by management on how best to further increase the potential sales of Jessop and Green River Steel Corp., Owensboro, Ky., an alloy-producing mill purchased early in 1957.

Plant facilities

The Washington, Pa., plant has three electric arc, 11-ft shell, top-charge Lectromelt furnaces in operation tapping approximately 15 tons of stainless and other high-alloy grades of steel per heat. A fourth electric arc, 9-ft shell, Heroult, top-charge furnace is being placed in operation in November. This new furnace has a capacity of 7 to 8 tons and will be used exclusively for the production of high-quality tool steels. Installation of the new furnace will make possible improved melting controls.

F. K. NOLL is assistant to the president and H. K. TAYLOR is vice president-operations, Jessop Steel Co., Washington, Pa.

The cold-scrap melting procedure is used at the plant. Known-analysis scrap, carefully selected and weighed, is loaded into charging buckets and subsequently charged into one of the furnaces. The heat of steel is melted as rapidly as possible and is refined under strict supervision. Upon completion of preliminary analysis of the molten metal by X-ray quantometer, and spectrographic and wet chemistry methods, proper alloy additions are made to adjust the heat of steel and to bring it into required customer specification limits. Temperature of the molten heat of steel is constantly controlled and recorded throughout the melting cycle, using immersion thermocouples. When the correct temperature of the molten metal is reached, the metal is poured into preheated ladles and cast into ingot molds of varying sizes under controlled casting temperature conditions. After ingots have solidified, they are removed from the molds and scheduled for further processing.

Ingots are charged into heating furnaces; hammer forged; bloomed or rolled into billets, blooms, or slabs; cut to proper dimensions; and fully conditioned. The conditioned intermediate products are returned to the finishing mills, reheated, and further processed into bars, billets, plates, sheets, and special sections.

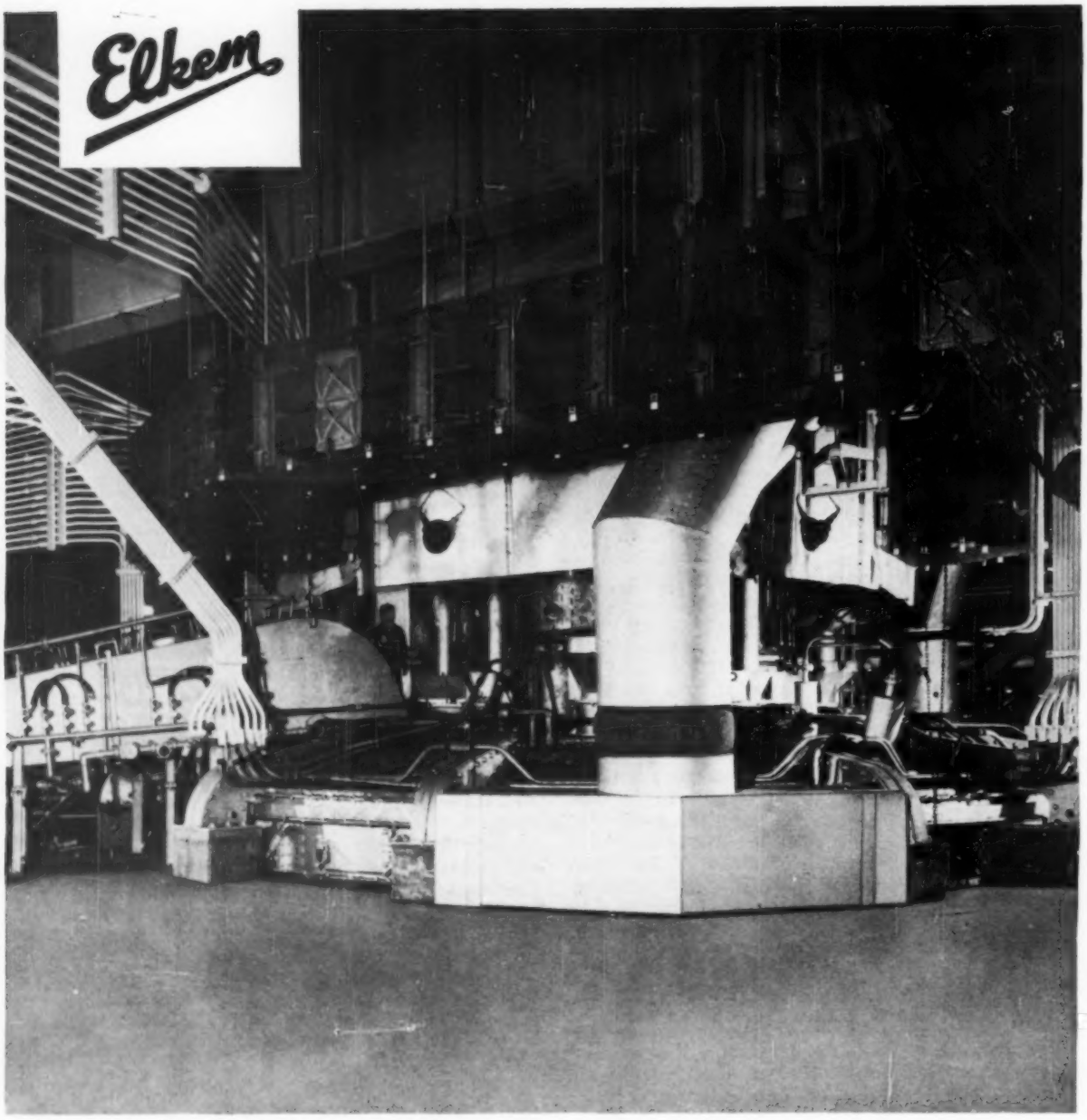
Plant rolling and forging facilities consist of the following equipment:

Mill	Size, in.	Description
Slabbing	66	2h—1 stand
Blooming	28	2h—1 stand
Bar	18	3h—5 stand
Bar	12	3h—5 stand
Bar	10	3h—7 stand
Sheared plate	32 × 96	2h—1 stand
Sheet	30 × 60	2h—1 stand
Sheet	30 × 72	2h—1 stand
Sheet	24 × 34	2h—4 stand

Forging Equipment:
Three forging hammers (2500, 6000, and 8000 lb).

Modern auxiliary equipment for annealing, pickling, flattening, straightening, shearing, and inspection, provides adequate finishing capacity. A cast-to-shape foundry div., composite metal div., and a precision ground tool steel div. complement the facilities of a fully integrated steel mill providing Jessop's customers with a full product line.

Jessop now has six plant locations in the United States and Canada, and under its present management which took office in 1950 when Frank B. Rackley was named president, the firm has grown from a relatively small specialty producer with sales of about $8 million annually to one of the leading integrated specialty mills with a combined sales potential of $60 million annually.



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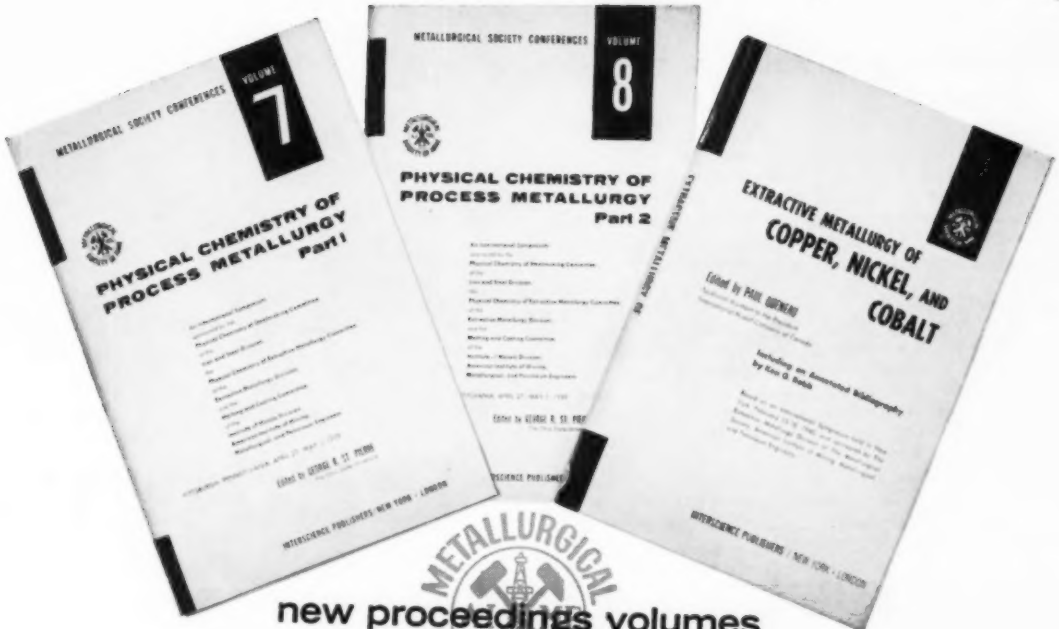
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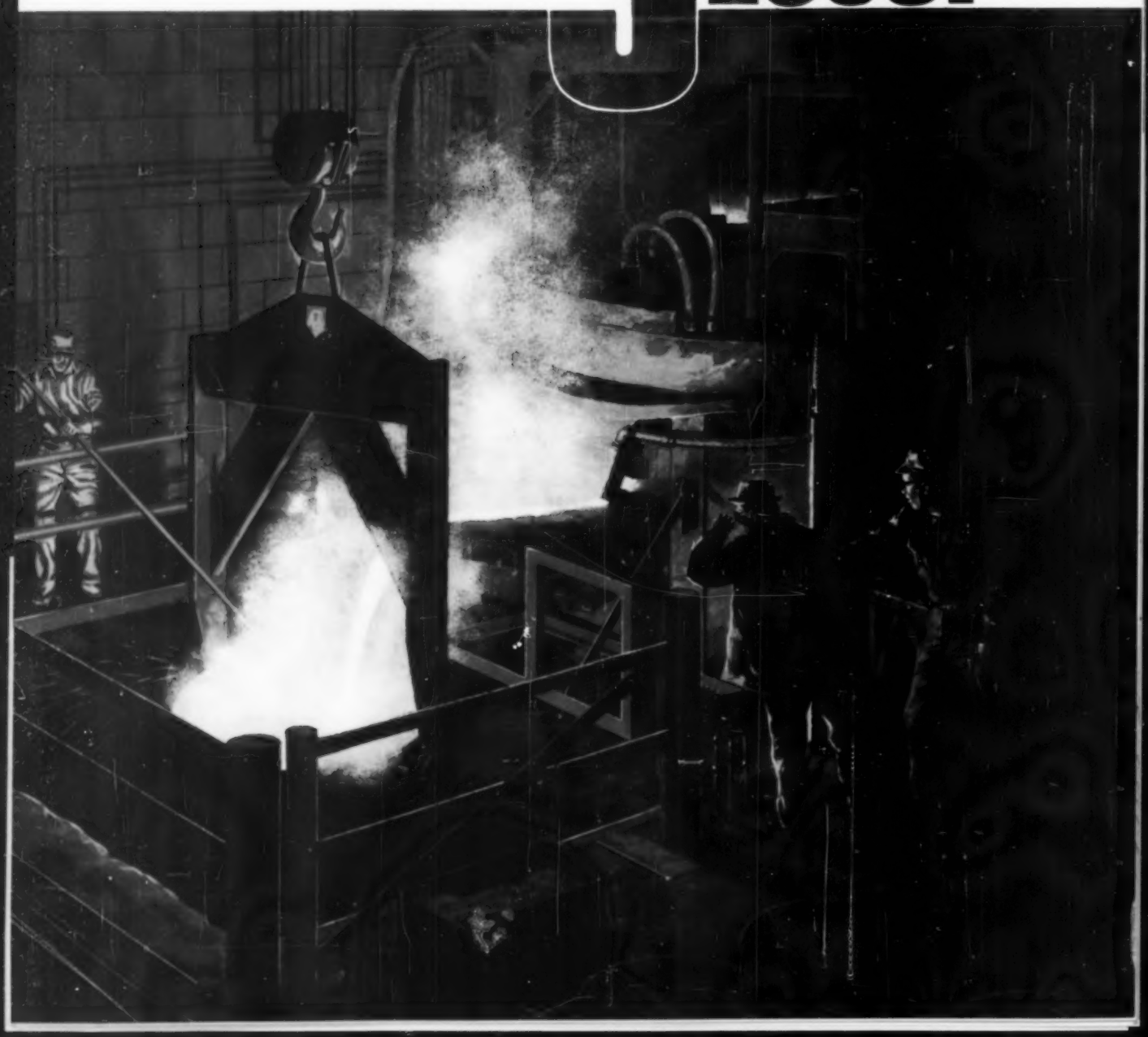


Some personal impressions of Communist China and its steel industry.

ONE QUARTER OF THE WORLD

Summarized from an article by H. W. A. Waring

No one can appreciate what is happening in China today unless he has seen it with his own eyes. No amount of vicarious experience can make up for that.

My first and lasting impression is that at the moment the Chinese are unabashed and uncompromising Leninists. No deviationism there! The idea of continuous revolution is a frightening thing and the idea of revolution by peaceful means is impossible.

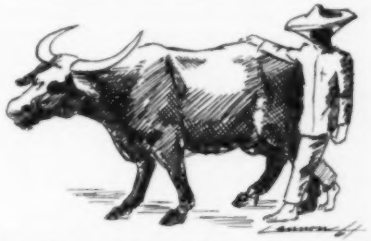
This may all sound rather flesh-creeping stuff, but it must be understood. The idea that we will swallow you someday—and make no bones about it—is deep in Chinese thought, perhaps more subconsciously than I have expressed it. The sequence is really that Communism will prevail over capitalism and, if Communism prevails, China, the largest nation in the world—670 million souls and 9.5 million square kilometers—is the natural leader.

Social compulsion

Before discussing industrialization, it is necessary to explain one thing. China does not give the impression of a police state. No doubt, at the outset a large number of landlords, capitalists and others were violently eliminated, but I must say very clearly that the country does not give the impression of domination by fear.

On the contrary, the earnest soul-searchings of young Communists are genuine, if deadly dull. As a correspondent of The Times recently put it, "China is a country that has been taken over by the young and which is burning up young energy. One may wonder how long the enthusiasm and the pace of work can be sustained. What compulsion there is, is social. This is, perhaps, the greatest compelling force in the world—keeping up with the Joneses (or in this case, the Wongs!). It is this social compulsion which produces PT squads in the streets at six in the morning; which enabled Peking to eliminate flies by two days' intensive fly swatting by the whole population. It also wiped out the sparrows of Peking when they fell dead in the streets after being kept continuously in the air for hours by the whole populace beating gongs and tin cans under every tree and on top of every building.

I do not want to make this social compulsion sound light-hearted. It is anything but that. The system is both ruthless and thorough and is administered through the 14 million



members of the Chinese Communist Party. The Chinese are subjected to an endless series of drives and campaigns—rectification campaigns, anti-rightist campaigns, drives against intellectuals, and reactionaries, and so on. They seem to spend much of their time in meetings, which encroach on working and leisure time. The object is to ensure that everybody is thinking correctly, both politically and ideologically.

The tide of industrialization

As I have mentioned industrialization is going on apace and the whole population, including the women, is at work. The female labor force is largely employed in rural and urban communes, but many women also work alongside the men in state-owned factories.

As my main interest lies in steel, I will deal with this is a little detail, but it should not, therefore, be inferred that other aspects of industrial development are neglected.

Chinese steel production is currently running at an annual rate of 18 million ingot tons. It is increasing at the rate of 4 to 5 million tons per year and by 1962 may well top the British figure, which currently is around 25 million tons.

The United Nations, in a recently published report, estimated production in 1972 as 52 million tons, but the Chinese poured scorn on this as being far too low. It may well be that they will make 70 million tons by 1970. Even at 52 million tons their rate of increase would be the highest in the world.

It must, however, be remembered that they started from very low levels. The present rate of consumption is around 66 lb per head and, allowing for a population increase to the staggering figure of 1,000 million people by 1970, their consumption would only be around 155 lb per head, as compared with a present figure of 1270 lb per head in the USA, 875 in the UK and 560 in the USSR. These figures show that they still have a very long way to go. Anyone who has been there cannot doubt the vast quantities of steel that will be required for roads, bridges, houses, and all forms of mechanized transport.

Much has been heard of the back-yard blast furnaces. These sprang up in hundreds around three years ago and consisted of very primitive units for smelting iron ore to produce any kind of iron to overcome local shortages. Some of the iron must have been very curious stuff indeed and most of them are now out of operation. Instead, a more sophisticated version is operating, producing around 300 to 700 tons a week, often in conjunction with a side-blown converter and a foundry cupola.

Walking on two legs

The Chinese often refer to "walking on two legs" and by this they

(Continued on page 891)

H. W. A. WARING is deputy chairman and general managing director of GKN Steel Co. Ltd., London. This is a summary of an article which appeared in the British Iron and Steel Federation's Quarterly, Steel Review, no. 22, April 1961.

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personals

H. H. Brandt has been appointed manager of industrial carbon sales for Collier Carbon & Chemical Corp. He joined the company in 1958 as as carbon sales representative.

William A. Bringman has been appointed assistant superintendent of the open hearth steel production department at Kaiser Steel Corp.'s Fontana, Calif., plant. He was formerly assistant superintendent of masonry.

Rene Castro, director of studies and research at the Société d'Électrochimie, d'Électrométallurgie et des Aciéries électriques d'Ugine, was awarded the Réaumur Medal during the Fall Meeting of the French Metallurgical Society, which was held in Paris, October 16-20. One of the Rist Prizes was awarded to **Jean Philibert** of IRSID.

Richard D. Chapman has been named chief of the Copper & Brass Research Assn.'s newly created office in Detroit, Mich. The office was set up to further market development and promotion of copper metals in the automobile industry.

Lawrence S. Darken, associate director of U. S. Steel's Edgar C. Bain Laboratory for Fundamental Research, presented the Campbell Memorial Lecture during the American Society for Metals' Congress and Exposition in Detroit.

Jay I. Dodson is now superintendent of the metallurgical department at Kaiser Steel Corp.'s Fontana, Calif., plant. He was formerly assistant superintendent of the department.

Alwin F. Franz has been named chairman of the board of Colorado Fuel & Iron Corp. He had been the company's president since 1952.

Vernon G. Kneeskern is now general manager of Reynolds Metals Co.'s Richmond, Va., reduction div. He was formerly assistant general manager.

Jack Kinnear, formerly general manager of the Nevada Mines div. of Kennecott Copper Corp., is now general manager of the company's western mining div. in Salt Lake City. He replaces **C. D. Michaelson** who has advanced to New York. **M. J. O'Shaughnessy** has replaced Mr. Kinnear.

Richard H. Lambert, associate director of the metals research laboratory and associate professor of metallurgical engineering at Carnegie Institute of Technology, has been awarded the A. V. de Forest Award given by the Society for Nondestructive Testing. The award is given annually for an outstanding contribution to the art of nondestructive testing.

Robert A. Lubker is now vice president of research and development, Alan Wood Steel Co. He joined the company in 1958 as director of research and development.

Wolfgang Matejka has been named to head Temescal Metallurgical Corp.'s high-vacuum foundry department. He was formerly with Kelsey-Hayes Co.

George T. Murray has been named vice president of research of Materials Research Corp. He was formerly director of research.

J. L. Oberg has been appointed vice president in charge of the minerals, ceramics, and welding divisions of Metal & Thermit Corp. He joined the company in 1955.

Guy Marshall Pound has been appointed Aluminum Co. of America professor of light metals at Carnegie Institute of Technology. He was previously professor of metallurgical engineering.

Adolph Joseph Scheid has been elected president of Columbia Tool Steel Co., succeeding **Arthur T. Clarage** who has retired after 47 years with the company. Mr. Clarage will continue as chairman of the board. **Adolph J. Scheid, Jr.,** (father of Adolph Joseph Scheid), vice president, manufacturing and quality control, has also retired.

Alvin G. Waggoner has become executive assistant to the director of research and systems engineering, Airborne Instruments Laboratory div. of Cutler-Hammer, Inc. He was formerly in the Office of the Secretary of Defense.

Gordon E. White has joined the staff of Reynolds International, Inc., for a special foreign assignment. He was previously superintendent of the Reynolds Metals Co. plant at Troutdale, Ore.

Frank Wills has been appointed technical manager of the Pyron Co., a division of American Metal Climax Inc.

Heinz G. F. Wilsdorf, technical director of Franklin Institute's solid state sciences div., **Marvin Herman,** laboratory manager; and **G. E. Spangler,** senior research metallurgist, presented papers at the Iron and Steel Institute's (London) conference on *The Metallurgy of Beryllium*, which was held in London October 16-18.

John S. Winston, head of the department of metallurgy, Mckay School of Mines, University of Nevada, has been named an honorary member of Alpha Sigma Mu, honorary metallurgical fraternity.

(Continued from page 871)

mean the operation of the small primitive plants, along with the giant integrated plants, such as Anshan and others in course of construction.

While there I visited two plants both partly completed. The first, at Wuhan on the Yangtze, will eventually have an output of 3.5 million tons of open-hearth steel and the second, near Peking, about 2 million tons. In both plants, the whole design and layout were completely Russian and the blast furnaces might have been taken straight from the Ukraine.

I questioned the wisdom of building large open-hearth plants with 500 ton furnaces in this day and age and asked their views on oxygen processes. On this they seemed very vague. I did suggest that I might meet their Minister of Metallurgy and have a discussion with some of their technicians, but this met with no response and there seemed to be no desire to open technical contacts with the West.

The plants themselves were scenes of the utmost activity and apparent confusion. There was a lamentable lack of mechanical equipment, but it is wonderful what pairs of hands can do, if there are enough of them. And indeed there were enough. At Wuhan there were 100,000 people on the site, half of them engaged on production and half on site work. The enormous numbers engaged on production were partly accounted for by the presence of large numbers of trainees, who would, in time, go on to other plants. Frankly, I did not have the impression that the open-hearth furnaces were working very well and the pitside was a scene of utter disorder. On the other hand, the big 2000-tpd blast furnaces, and coke ovens, sinter plants, and all that side seemed to be working well.

If I have dwelt a little long on this side of industrialization, it must not be assumed that other and secondary industries are not keeping pace. They are indeed. The Chinese are producing lorries and tractors but not, except perhaps on *one-off* basis, passenger cars. They did show at the Canton fair a large, ostensibly Chinese-made limousine, looking remarkably like a Russian Zis, but I never saw any on the streets, where most of the few cars visible were Russian, Czech, or Polish, with a few odd ones from the West thrown in.

Transport and air and rail service

China has not yet arrived at the automobile age. Taxis, apart from cars used for foreign visitors, are normally cycle rickshaws, and there is much horse- or mule-drawn, or even human-drawn transport. China is developing its railway system considerably. The established lines run in quite a normal manner. It is, however, interesting to note that, in the train from the Hong Kong border to Canton, the carriage we were in had loose arm chairs facing each other, which gave a great sense of freedom and mobility but was probably not very practical for space-saving.

Many new railways are being blasted through the rocks and laid in most difficult country. There is, on the whole, an extreme shortage of both heavy and light rails. I did hear that in some remote districts the shortage of steel was so great that wooden and even glass rails had been put down.

The Chinese have an extensive internal air service, operated by Russian machines carrying about 24 passengers. These, we found, were competently handled, but obviously had no great ceiling and operations were considerably hampered when the weather was bad.

External lines, with the exception of those from the USSR, do not go into China, and the Chinese are therefore dependent on the Russians both for their airplanes and for flying techniques. The airports appear to be used both for civilian and military purposes and at the various airports at which I landed large numbers of modern Russian fighters were drawn up or were taking off at frequent intervals.

At present, trade is dominated by Russia. Russian technicians and machinery are everywhere and Russian methods predominate. It is calculated that 75 pct of Chinese foreign trade is with the Soviet Union.

I do not think this will continue indefinitely. The Chinese are not a nation to be dominated in the long run and, if I were a Russian, I would be a little uneasy about those vast open Siberian spaces just on the other side of the Gobi Desert. They looked invitingly empty, after the crowded plains of China, as I flew over Siberia from Irkutsk to Moscow.

Conclusions

In the course of this article I have tried to give as unbiased a view as possible of the small amount of the Chinese scene which I personally saw. All too many accounts of China are based on the one hand on reports from wishful thinkers, who can only see the bad, and on the other, on the praises sung ad nauseam by fellow travelers. I have attempted to steer between these two extremes.

I would emphasize that when you start with an underfed, badly-housed, illiterate, and superstitious people you can do an enormous amount in a few years through enthusiasm. Whether this burning zeal and deadly seriousness of purpose can continue indefinitely is another matter.

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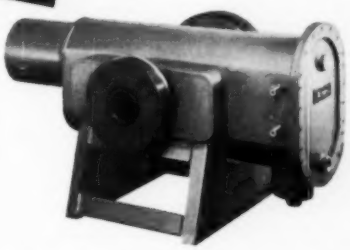

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The theme for the first day of the conference will be *High Strength and High Temperature Brazing Alloys;* the second day, *High Strength Material Welding,* and the third day, *Stress Analysis of Joints.*

The fee for the symposium is $50; the conference is planned for research, design, and development engineers.

Chairman of the symposium is Karl M. Weigert, assistant professor, industrial engineering, Penn State.

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The joint sponsors of the conference are Rensselaer and the Watervliet Arsenal. Cooperating with them are government agencies and other universities. The general chairman will be R. E. Weigle, director of research, Watervliet Arsenal. The conference keynote at the December 18 opening session will be sounded by Maj. Gen. Willian. Ely, director of the Army Research Offce.

Session I will be a general review of materials research programs. Session II will include five papers on solid-state physics and four on metallurgy. Session III will include six papers on solid state physics and six on mechanics research. Session IV will have six papers on metallurgy and seven on polymer chemistry.

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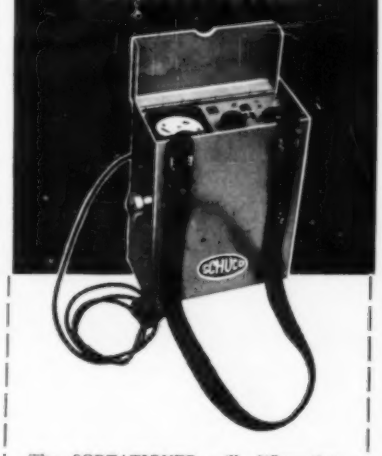

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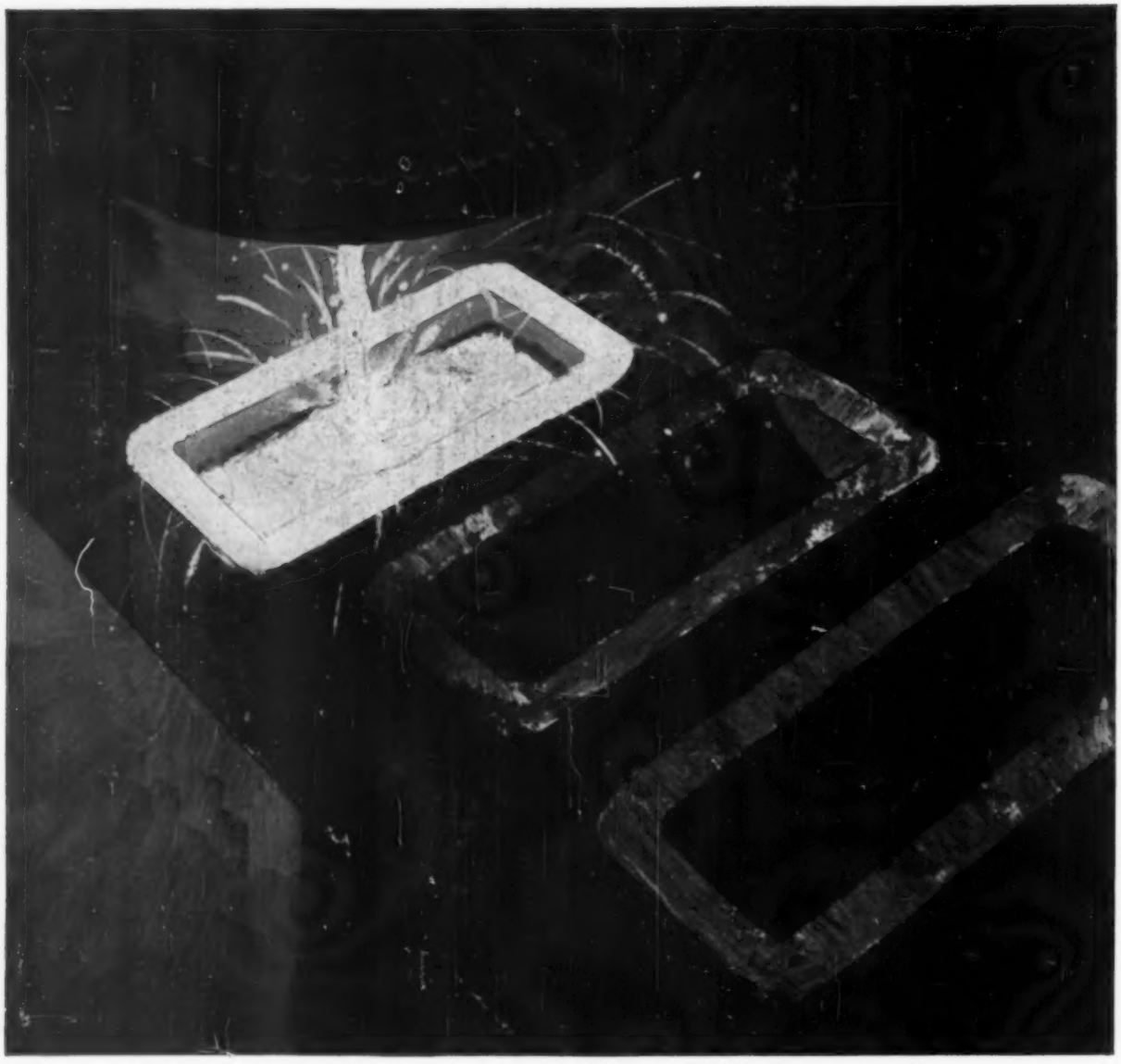

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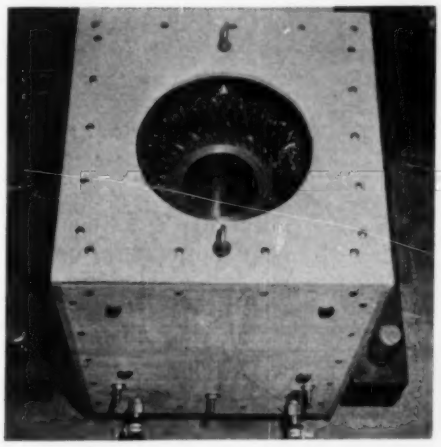
Solidification in a moving electromagnetic field has been successful in altering the as-cast grain structure of steel ingots. Some of the experimental results were obtained with the equipment shown at right, Fig. 1.



GRAIN REFINEMENT BY SOLIDIFICATION IN A MOVING ELECTROMAGNETIC FIELD

by F. C. Langenberg, G. Pestel, and C. R. Honeycutt

The grain structure of a steel ingot teemed into a metal mold can be defined by macroscopic examination in semi-quantitative terms. For example, the relative volume of obviously differing structures can be estimated with the classic definitions of chill, columnar, and equiaxed zones. Experimental evidence has proved that the grain structure of an ingot is affected by changes in such factors as teeming temperature, rate of teeming, degree of turbulence, size of ingot, mold characteristics (including pre-heat temperature, design and coating), and composition of the metal (especially as it affects the range of solidification).

Significant advances have been made by fundamental solidification studies, but the principles which have been developed are difficult to apply to the complex and changing phenomena that occur simultaneously during ingot solidification. In particular, many attempts have been made to refine the as-cast structure of ingots, with special emphasis on the columnar grains. The formation of large columnar grains is generally considered harmful to the further fabrication of an ingot. It may also result in undesired anisotropic properties. However, columnar grains are not undesirable in all grades (or product applications), and caution must be exercised to determine in which grades and applications columnar grains are not desired in the ingot.

Although the literature on the refinement of as-cast ingot grain structures is too vast to review here, it is noteworthy that such methods as additions of artificial nuclei, mold vibration, mechanical stirring or ultrasonic agitation of the molten metal, and controlled cooling and reheating during solidification have been tried with varying degrees of success. However, it is doubtful that any method of refining the as-cast ingot grain structure has been completely successful on a commercial basis.

F. C. LANGENBERG, G. PESTEL, and C. R. HONEYCUTT are with the Crucible Steel Co. of America, Pittsburgh, Pa.

The purpose of the investigation reported here was to determine the effect of electromagnetic stirring upon the as-cast grain size and structure of laboratory-size steel ingots. During solidification, the liquid metal in the mold was caused to rotate about a vertical (longitudinal) axis by a similarly rotating magnetic field.

Electromagnetic stirring

In general, electromagnetic stirring of metal is analogous to the operation of an induction motor. When a magnetic field is moved with respect to an electrically conducting material, currents are induced in that material. These currents, in effect, create a secondary magnetic field of such polarity that the interaction between the primary and secondary fields results in a force which tends to drag the conducting material along with the primary field (Lenz's Law). The force exerted on the conducting material is directly proportional to the square of the intensity of the primary field, and inversely proportional to the resistivity of the material. In electromagnetic stirring, the pole pieces surrounding the mold can be compared with the stator of an induction motor, while the molten metal acts like a rotor. Thus, viewed purely as a field phenomenon, rotation of the molten metal is caused by the torque resulting from the interaction bebetween the magnetic fields of the *stator* and the *rotor*. An equivalent view would be to regard the torque on the molten metal as similar to the force exerted on a current-carrying conductor in a magnetic field.

The theoretical rotational speed of the magnetic field produced by an induction stator-type device can be calculated from

$$R = \frac{120\,f}{P} \qquad [1]$$

where R equals the rotating speed of the field in rpm, f is the power frequency in cps, and P is the

Table I. Experiments on Solidification in a Moving Electromagnetic Field

Heat No.	Type of Steel	Mold	Pouring Temp, °F	Test Conditions	Power Input to Stator, kw
1	410	Ceramic, 4-½-in. ID	2900	No field applied	—
2	410	Ni-Resist, 4-⅜-in. ID	2900	No field applied	—
3	410	Ni-Resist, 4-⅛-in. square	2900	No field applied	—
4	410	Ceramic, 4-½-in. ID	2900	Field applied 6 min	10.5
5	410	Ni-Resist, 4-⅜-in. ID	2900	Field applied 3 min	10.5
6	410	Ni-Resist, 4-⅛-in. square	2900	Field applied 3 min	10.6
7	410	Copper, 4-⅜-in. ID	2900	Field applied 3 min	10.5
8	410	Copper, 4-⅜-in. ID	2900	No field applied	—
9	410	Ni-Resist, 4-⅜-in. ID	2770	No field applied	—
11	302	Ni-Resist, 4-⅜-in. ID	2770	Field applied 2 min-50 sec	22.1
19	310	Ni-Resist, 4-⅜-in. ID	2810	Field applied 2 min	6.2
21	310	Ni-Resist, 4-⅜-in. ID	2810	No field applied	—
30	310	Ni-Resist, 4-⅜-in. ID	2810	Field applied 38 sec	10.8

number of poles formed by the magnetic field in the stator. In practice, the molten metal will not revolve at the theoretical speed, just as a practical induction motor rotor will not revolve at the synchronous speed of the stator field. In this investigation, the rotational speed of the molten metal was controlled by varying the stirring field intensity, through control of the voltage impressed on the windings. However, as shown by equation [1], this speed is also dependent upon the power frequency and the number of poles. For large ingots, frequency control could possibly be more practical than voltage control.

This principle has previously been applied in somewhat different form, to refine the as-cast grain structure of metal ingots. In 1933, experiments with a rotary magnetic field were performed at the Urals Physico-Technical Institute.[1] Zinc, aluminum, and aluminum bronze were stirred by a rotating electromagnetic field during solidification in small ceramic or asbestos molds (0.8x1.8 in. by 1.2 in. deep). The rotation of the stirring field, however, was around a horizontal axis, and the forces acting on the metal produced a tumbling motion. Further work was done at the same institute with a 0.6 pct C-3 pct Ni steel and with a 0.2 pct C-25 pct Ni steel.[2]

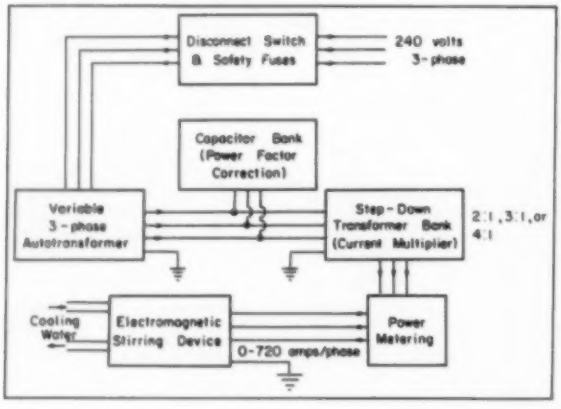
A similar type of magnetic stirring has also been used in consumable-electrode vacuum arc melting. Rotation, in this case, is produced in the metal pool by the interaction between an externally-applied magnetic field and the arc current flowing through the pool. The rotation of the molten metal is about a vertical axis, but it quickly ceases when the arc current is interrupted.

Equipment

Fifty-pound heats melted in an induction furnace were poured into molds located in the stirring field. The mold was keyed into the field device to prevent it from also spinning in the electromagnetic field. The molds used were all externally cylindrical in shape (6¼ in. OD) and for most runs had cylindrical inside cross-sections; They were the big-end-up type and were made of Ni-Resist cast iron (2.40 pct C, 2.30 pct Mn, 3 pct Si, 23 pct Ni, 0.40 pct Cu, bal. Fe) and copper. Non-ferromagnetic molds were necessary to permit the rotating electromagnetic field to penetrate into the molten metal. Also used were ceramic molds, which consisted of an inner cylinder of 20-gauge low-carbon sheet, an outer cylinder of austenitic stainless sheet, and in between dry MgO packing. The top surface of the rotating metal, which assumes a parabolic shape during stirring, must be contained by a hot top shaped like a truncated cone to prevent loss of metal during stirring.

The stirring field device was made by rewinding the stator of a 15-hp, 25-cycle induction motor for six-pole operation (theoretical rotational field speed of 1200 rpm). The inside diameter of this device was 6½ in. A copper-tubing winding (for water cooling), specially insulated for high-temperature operation, was installed in the stator.

Fig. 1 shows the field device inside a protective transite case. A diagram of the electrical power



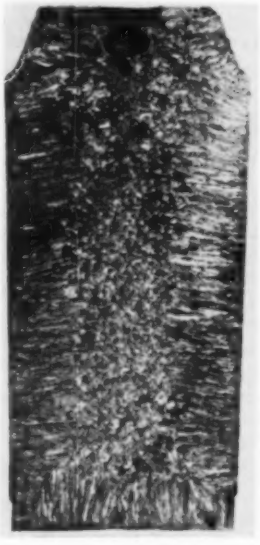


Fig. 2—Above, Electrical power circuit. Fig. 3—Right, Macrostructures of Type 410 Stainless 4⅜-in. diam ingots poured into Ni-Resist molds; a (left) no field applied, b (right) field applied.

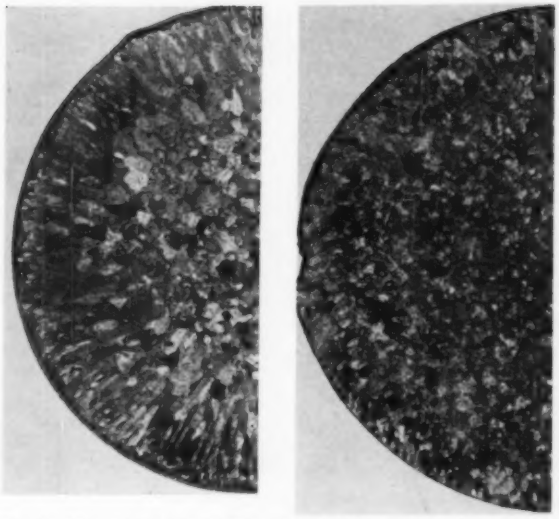


Fig. 4—Macrostructures of Type 410 Stainless 4½-in. diam ingots poured into ceramic molds with 0.0375-in. steel liners; a (left) no filed applied, b (right) field applied.

control and metering equipment used in this work is shown in Fig. 2.

Procedure

The melts were made under an argon atmosphere. To permit effective melt control, periodic measurements were made with immersion thermocouples and an indicating recorder. When the melt was at the proper tapping temperature, the metal was poured into a funnel placed on top of the hot top. The funnel nozzle was replaced after each heat to ensure a constant pouring rate.

For those heats in which the ingot was cast in the rotating electromagnetic field, the desired field intensity was applied before tapping. It is important to emphasize that the magnetic field was present when the molten metal first entered the mold. The times listed in Table I are from start of pour to power off. Even for the heats in which a magnetic field was not applied, the molds were placed in the stirring device to minimize such variables as pouring rates, distance from crucible to hot top, and cooling rates.

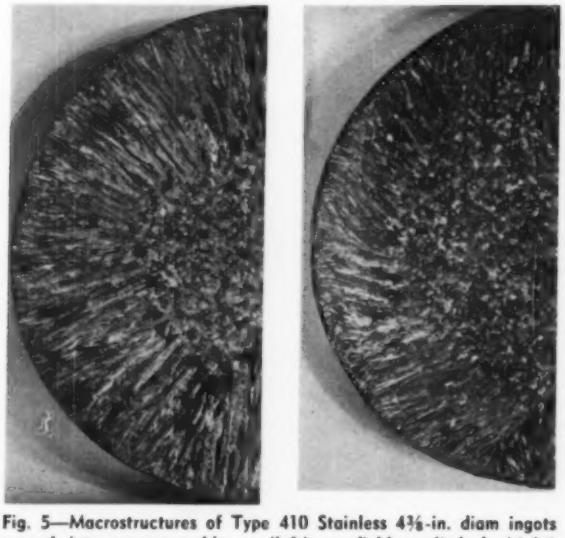


Fig. 5—Macrostructures of Type 410 Stainless 4⅜-in. diam ingots poured into copper molds; a (left) no field applied, b (right) field applied.

Grain refinement of various alloys

The effect of electromagnetic stirring on ingot structure is best illustrated by photographs of polished and etched ingot sections. Although all of the grades evaluated in this program cannot be discussed in this paper, the results for a few typical grades are presented. The heat number for each macrostructure is indicated on the figure and reference can be made to Table I for the process variables.

Type 410 Stainless

Fig. 3 shows the longitudinal cross sections of two 50-lb ingots of Type 410 stainless cast into Ni-Resist molds (a) with no field applied during solidification, and (b) with field applied. The refinement of the as-cast grain structure is obvious. The columnar grains in Fig. 3a are almost completely absent in the refined ingot (Fig. 3b) except for a zone at the bottom of the ingot where rapid solidification occurred. In addition, the equiaxed grains in the refined ingot are much smaller and are uniform from top to bottom of the ingot. In subsequent comparisons, macrostructures of transverse sections from the middle of ingots are presented.

In Fig. 4 cross sections are shown of ingots of 410 stainless cast into ceramic molds with and without the electromagnetic field. The as-cast ingot structure without the field (Fig. 4a) shows a smaller columnar zone than is present in ingots cast into all metal molds. However, the application of the electromagnetic field during solidification still resulted in marked refinement of the grains. (Fig. 4b).

Fig. 5 shows macrostructures of Type 410 stainless ingots cast into copper molds. These molds have a greater chilling effect than the Ni-Resist or ceramic molds, and as expected, the columnar zone in the ingot cast without the electromagnetic field is quite large (Fig. 5a). Although the ingot solidified in the electromagnetic field still shows columnar crystals (Fig. 5b), these columnar crystals are shorter and bent in the direction of stirring.

Fig. 6 illustrates the macrostructures of refined and nonrefined ingots of Type 410 stainless cast into square Ni-Resist molds. Fig. 6a is a classical example of ingot structure showing the chill, columnar, and equiaxed zones. As shown in Fig. 6b, electromagnetic stirring results in considerable refinement of the grain structure. The refinement, however, is not as pronounced as with round ingots. This difference is probably due to turbulence in the corners of the square molds. However, it should be possible to design a stator that could overcome this difficulty.

Type 302 and 310 Stainless

Fig. 7 shows transverse cross sections of two 50-lb ingots of Type 302 stainless cast into Ni-Resist molds. The ingot cast without the electromagnetic field (Fig. 7a) is almost entirely columnar, a characteristic typical of austenitic stainless steels. On the other hand, the comparison ingot cast into the electromagnetic field (Fig. 7b) shows outstanding grain refinement. The hexagonal pattern in the refined ingot is probably related to the design of the six-pole stirring device, although the mechan-

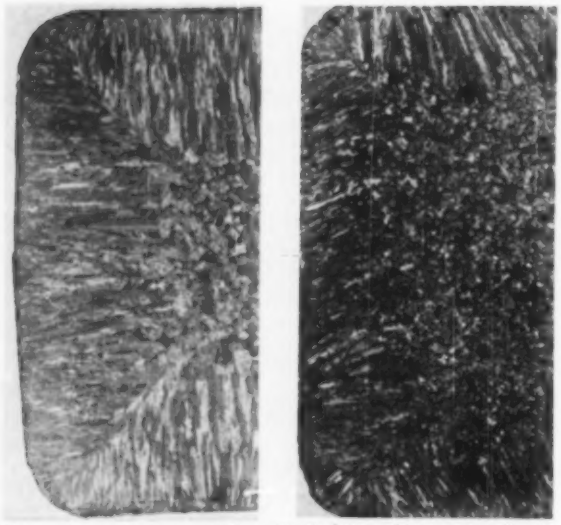


Fig. 6—Macrostructures of Type 410 Stainless 4⅛-in. square ingots poured into Ni-Resist molds; a (left) no field applied, b (right) field applied.

ism for such an unusual structure has not been determined.

Fig. 8 compares the as-cast and electromagnetically stirred structures of Type 310 stainless ingots. As with Type 302 stainless, the grain size of this somewhat difficult-to-hot-work grade is refined by electromagnetic stirring.

For optimum grain refinement

During the experimental program, the field intensity in the mold was found to be quite important. Excessively high field intensities result in too rapid rotation of the liquid metal, which can cause the metal to overflow the mold or cause center porosity in the ingot. If the field intensity is too low, grain refinement will not occur.

In order to determine the variation of field strength in the molds as a function of phase current or line-line voltage, a series of experiments were performed. The magnitudes and directions of the magnetic field within each mold at various radii

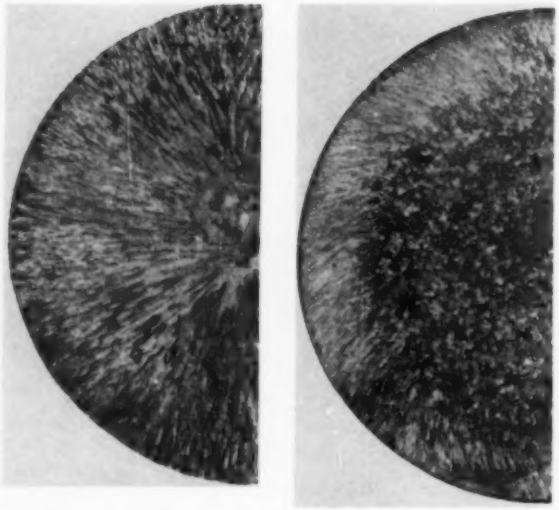


Fig. 8—Macrostructures of Type 310 Stainless 4⅛-in. diam ingots poured into Ni-Resist molds; a (left) no field applied, b (right) field applied.

were determined with a magnetic probe and oscilloscope.

Utilizing the field intensity measurements and the results of a series of casting experiments at various flux densities, an empirical design constant was developed, and its range for optimum grain refinement was established. This design constant is proportional to $\frac{wH^2a^2}{r}$ where **w** is the rate of rotation of the magnetization vector within an element of metal near the liquid-solid surface in radians per sec, **H** is the magnetic field intensity in oersteds, **a** is the radius from the mold center to the liquid-solid interface, and **r** is the electrical resistivity of the molten metal. Further information on the design constant is presented in US Patent No. 2,963,758, *Production of Fine Grained Metal Castings*, which has been issued to the authors of this paper.

In defining the conditions for optimum grain refinement, it is necessary for some grades of steel

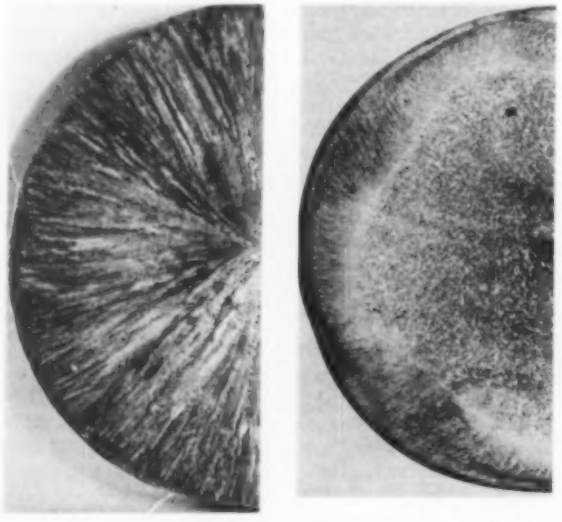


Fig. 7—Macrostructures of Type 302 Stainless 4⅛-in. diam ingots poured into Ni-Resist molds; a (left) no field applied, b (right) field applied.

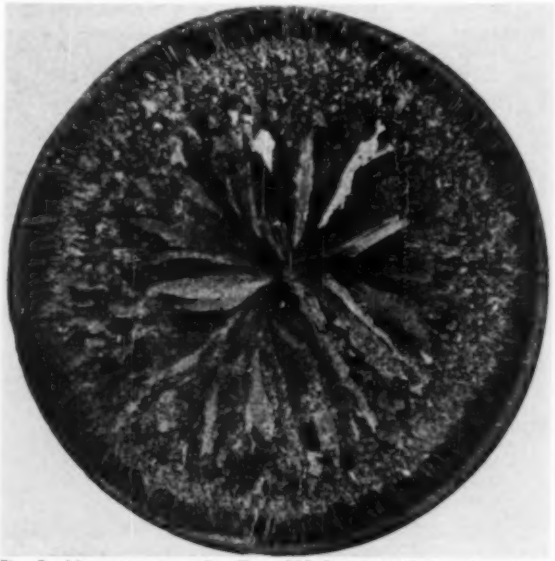


Fig. 9—Macrostructure of a Type 310 Stainless 4⅛-in. diam ingot poured into Ni-Resist mold with field removed after 38 sec.

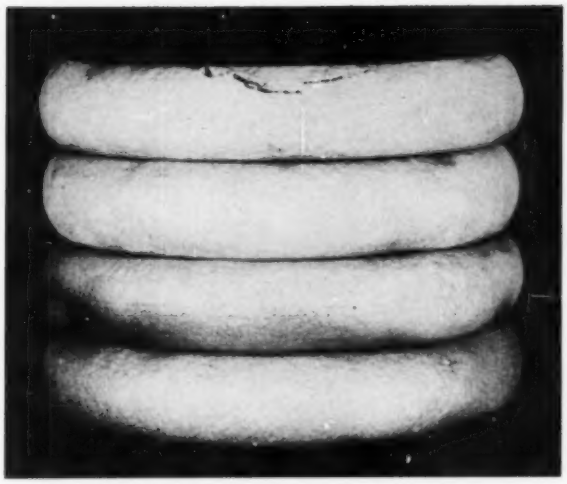


Fig. 10—Forged disks of Type 310 Stainless after a 3 to 1 reduction in thickness. (Top disk from an ingot cast without electromagnetic stirring while the bottom three disks were from grain refined ingots cast with electromagnetic stirring.)

to separate the ingot solidification into an early stage where columnar grains normally appear and a later stage as solidification approaches the center of the ingot. In the latter stage, center porosity may occur, above a critical value of field intensity. As a rule of thumb for those grades where center porosity is a problem, the authors found that the power input for optimum refinement of columnar grains should be reduced by one-half after the ingot is half solidified.

The basic solidification pattern of the steel is also quite important in determining the correct power input during final solidification. For example, Type 410 stainless normally solidifies with equiaxed grains in the center (Figs. 3a, 4a, 5a, and 6a); thus, even when the field was entirely removed after the ingot was half solidified, the center portion of the ingot was still equiaxed. On the other hand, types 302 and 310 stainless normally solidify with grains almost entirely columnar from surface to center (Figs. 7a and 8a). For such steels, if the field were removed after solidification was half complete, the columnar grains would reappear. This was confirmed by experiment as shown in Fig. 9. It is obvious that the columnar grains become re-established after the field was cut off. Center porosity can be offset in this type of steel by maintaining the field at reduced (one-half) intensity in the final stages of solidification to prevent center porosity and yet to continue breaking up the coarse columnar grains.

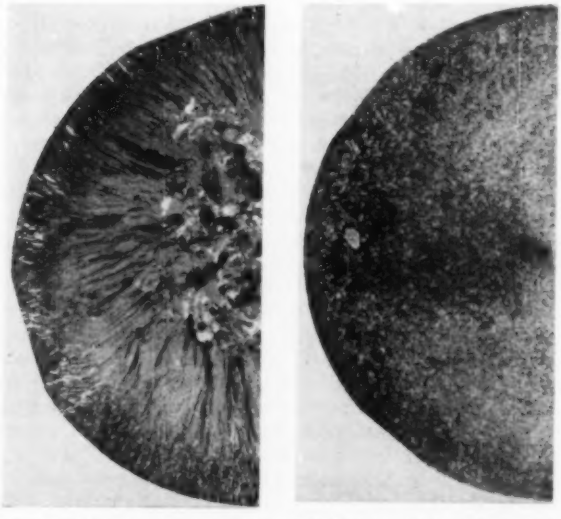


Fig. 11—Macrostructures of Type 310 Stainless disks after upset forging from 3 in. to 1⅛-in.; a (left) without electromagnetic stirring, b (right) with electromagnetic stirring.

It appears from the above experiment that, when the stirring stops, the system rapidly adjusts to the normal mass transfer and heat transfer conditions which are almost entirely dictated by the thermal characteristics of the solidified metal and the mold. Thus, the solidifying steel returns to the typical mode of freezing which would occur without stirring.

Effect on hot workability

All the ingots made in this investigation were evaluated for hot workability by forging, on a 2,000-lb hammer, 3-in.-thick disks cut from the ingots. In no instance was the hot workability of grain-refined ingots inferior to that of normally cast ingots. For several grades, the hot workability of the grain-refined ingots was superior. However, it should not be assumed that grain refinement is a cure-all for hot workability problems. It does not necessarily follow that an ingot with a fine as-cast grain size will always have better hot workability than an ingot with a coarse as-cast grain size.

Fig. 10 shows four disks of Type 310 stainless which were reduced in thickness from 3 in. to 1 in. by upset forging. The top disk was from an ingot that solidified without a field applied; the bottom three disks were from ingots that solidified in the moving electromagnetic field. There were surface cracks in the disk from the normally cast ingot, but no cracks were present in the three disks from the refined ingots.

Fig. 11 shows macroetched sections of two of the Type 310 stainless forged disks after the 3 to 1 reduction in thickness. Fig. 11a shows the disk from the conventionally-cast ingot (top disk in Fig. 10); the structure in this figure should also be compared with the as-cast structure of the non-refined 310 ingot shown in Fig. 8a. The as-cast columnar grains still exist after forging. Fig. 11b illustrates a disk from a grain-refined ingot; the macrostructures show no large grains and should be compared with the refined as-cast structure shown in Fig. 8b. Note particularly that the thin and bent columnar grains in the as-cast, stirred ingot are almost completely broken up by the forging.

Scale-up

The electromagnetic stirring process has been scaled up to 13.5 in. diameter ingots weighing 1300 lb. Many grades were evaluated, and in most cases grain refinement was accomplished. However, problems typical to the scale-up of solidification processes have arisen, and further work is necessary to define the conditions for optimum grain refinement and product quality.

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HOT METAL PRE-REFINING FOR ELECTRIC FURNACE STEELMAKING

A progress report on new Brymbo hot metal pre-refining process for electric steelmaking described in the August 1959 issue of JOURNAL OF METALS, *this article presents operating data from the second pre-refining campaign conducted from January 1960 to August 1961.*

by E. Davies

Brymbo Steel Works is located in the north east industrial region of Wales. The coal measures were worked in this area during the early seventeenth century, and iron was produced in North Wales as early as 1720 to 1730. It was, however, not until the late eighteenth century that the Brymbo blast furnaces were built. The essential raw materials: coal, iron ore, limestone (both calcium and magnesium), silica stone, and high alumina clays were available within an area of some 2 to 3 miles of the works. The first basic open-hearth furnace in the British Isles was commissioned at Brymbo in 1884, and in 1890 the first by-product coke ovens were built.

Developments at Brymbo

During early 1939 work was commenced on a new melting shop for the production of alloy steels, and later three 18-ton Siemens Schuckert arc furnaces were installed. At the end of the War it was realized that the old open-hearth shop was rapidly becoming obsolete and a decision would soon have to be made regarding its future. At this time scrap was in short supply, and the need to increase the amount of hot metal in the charges imposed a heavy metallurgical load upon the furnaces.

The solution to this problem was found in 1948 when trials began with the oxygen lance as a pre-refining tool. By 1951 the use of oxygen for desiliconizing the blast furnace metal was a regular production feature.

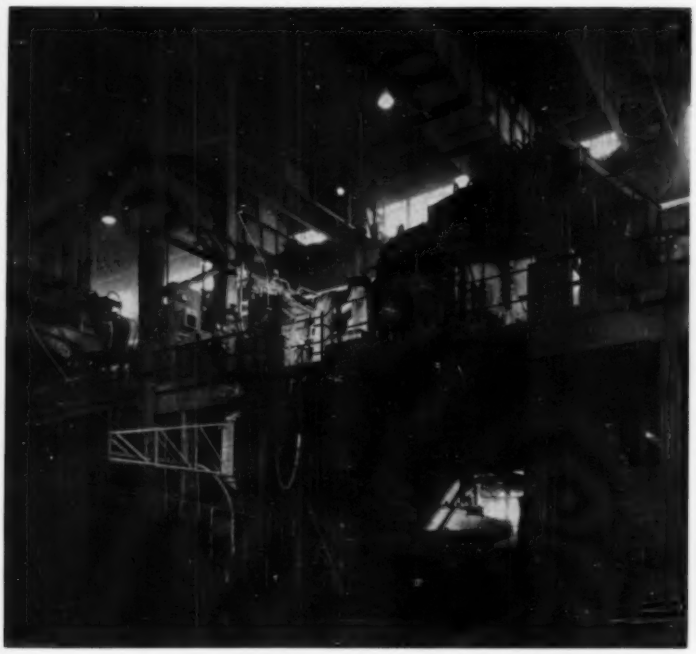
Later it became clear that, not only could silicon be removed from the blast furnace metal but, by combining the use of oxygen and basic oxides in granulated form, it was possible to reduce the phosphorus content also without serious loss of carbon. This was a development of the utmost importance, for it meant that the hot metal process could now be extended to the electric furnace which, hitherto, had been primarily regarded as a scrap melter. Thus, the *Brymbo Process* crystallized, and the way was now clear for using large quantities of pre-refined blast furnace hot metal in the electric furnaces. This fitted in perfectly with the Company's ideas for the new development scheme, because, unlike other steelworks which have installed large electric furnaces to work the conventional 100 pct scrap process, Brymbo wished to continue the operation of the blast furnace.

E. DAVIES is managing director, Brymbo Steel Works, branch of GKN Steel Co. Ltd., Brymbo near Wrexham, northern Wales. This paper is being presented at the 1961 Electric Furnace Conference in Pittsburgh, Pa.

Designing the vessel

On previous occasions, attempts have been made to use blast furnace metal directly in electric furnaces, but they have been abandoned in favor of all cold scrap charging. Unlike the open hearth which has an extensive system of flues and ducts enabling a constantly oxdizing atmosphere to be maintained over the charge within the hearth, the arc furnace treats the metal in a more or less sealed-off chamber in an atmosphere which is virtually non-oxidizing and which can be made reducing if so desired. The result is that it is difficult to remove silicon, phosphorus, and more than 3 pct C from molten metal in an electric arc furnace. As previously indicated, efforts to do this have rarely proved economical, and occasionally in the *Ore process* violent ejections of slag and metal through the doors make the process highly dangerous. In such cases a certain measure of pre-refining is not only desirable but essential.

For many years desiliconizing was carried out in ladles, but when this was extended to remove both silicon and phosphorus the ladle was found to be unsuitable. When the silicon content of the iron exceeds 0.50 pct, slopping and foaming usually occur, clean slagging off is difficult, and the whole process is messy and undesirably long. In order to carry out this work satisfactorily, therefore, it was necessary to design a special furnace or vessel within which this process could best be worked practically and economically. The importance of adequate slag/metal surface area was evident, and it was desired to have sufficient bath agitation without having to incorporate means for rotating the hearth. Provision for fume extraction and the



View of Brymbo's pre-refining furnace below stage showing air ducting and oxygen equipment.

control of foaming had to be considered, and the choice of suitable refractories was important. It was also desirable that the furnace could be fettled when required between heats. In addition, provision should be made for burning-in such fettling material as well as the initial burning-in of the hearth. Trials were carried out both in open-hearth furnaces and in an electric furnace bowl, and with certain modifications it was evident that the latter was the most suitable type to install.

In the first instance, the fume off-take was connected to the side of the vessel, but, owing to the undermining of the upper walls, this was later changed to a central position in the roof. The roof is built of high-alumina bricks and is portable; roof changing can be carried out in the same manner as the electric arc furnaces.

To ensure the high temperature necessary to burn-in the hearth lining, it was decided to enrich the combustion air with oxygen tapped off the main supply, thus attaining flame temperatures of about 2000° C. This has been achieved in a unique manner: The duct carrying the combustion air passes inside the furnace and under the hearth brickwork, giving a two-fold effect; a small measure of pre-heat is obtained and the sub-hearth is cooled by the constant flow of air through the ducts. Oxygen enters the duct at a point below the secondary air fan. Some 10 pct oxygen enrichment has been found to give adequate flame temperature to burn-in the hearth and any fettling material which may be used between heats. In order to contain and control the foaming slag, the hearth was deliberately made deep—4 ft 10 in. to sill level—and the oil burners were incorporated and mounted tangentially in the walls. The intensely hot flame serves a dual purpose by *knocking down* the foam and, at the end of the process, keeping the slag open until tapping is completed. This also effects an appreciable reduction in the Fe content of the slag.

The hearth is 16 ft in diameter, giving roughly 6 sq ft per ton of iron. The vessel rests on rockers and rollers, facilitating tilting to angles of 20° for slagging and 40° for tapping. The axis of tilt is so arranged that, at all angles, the water-cooled duct for removing fume and products of combustion remains in full operation.

Furnace refractories

For the first campaign, a graded tarred dolomite hearth was installed above the magnesite sub-hearth with side walls of tarred dolomite bricks. The area adjacent to the tap-hole was magnesite, and the tap-hole was formed and molded with basic (doloset) cement. High alumina (65 pct Al_2O_3) bricks were chosen for the roof and lining of the fume off-take.

From experience gained during the first months of operation, it became obvious that dolomite was not a suitable hearth material. And the next installation was made up of 9 in. of graded *Britmag* vibrated into a well-consolidated layer above the magnesite brick sub-hearth. Above this was a layer of 3 in. of magnesite enriched dolomite in the proportion of 25 pct magnesite and 75 pct dolomite —both finely graded and again consolidated with vibratory roller.

The banks were made of this same material, and the results have been highly satisfactory as the records indicate. The refractory lining was thoroughly burnt in with the oxygen/oil burners, and the liquid slag allowed to set back before the first charge. The attention and time paid to the burning-in operation has been amply repaid, and

Table I. Results of the Second Pre-Refining Campaign, 4219 Heats, January 23, 1960 to August 5, 1961[a]

	Blast Furnace Hot Metal		Scrap Used		Total Charge, tons	Pre-Refined Hot Metal Produced, tons	Yield, pct	Oxygen Consumption, cu ft[b]	Lime Consumption, lb/ton	Fettling, Dolomite Consumption, lb/ton[c]
	Total, tons	Pct Charge Wt	Total, tons	Pct Charge Wt						
Total	89,002	89.86	10,043	10.14	99,045	91,727	92.61	819	79.57	2.06
Per Heat	21.10		2.38		23.48	21.74				

Refractories	Life, No. of Heats	Consumption, lb/ton
Hearth (Continuing)	4219	1.62
First Side Wall	1391	3.59
Second Side Wall	2828	2.28
Roof	300	7.27

[a] All tonnages in long tons unless otherwise specified.
[b] at 100 pct efficiency.
[c] 1961 to date 1.27 lb/ton.

the hearth has completed 4219 heats up to the week ending August 5, 1961. It is still in first class condition.

Fettling the furnace between heats is carried out in a unique manner. Lime powder dispensed at a pressure of 2 atms is pneumatically injected directly from a bunker onto the side walls, banks, and hearth of the furnace. The maximum delivery rate of the lime powder is 1 cwt per min. This is carried out when the furnace is at a high temperature and the banks and walls are in a tacky to wet condition. By this means, the linings are protected and indeed built up in an economical way so that fettling is greatly simplified and considerable savings in dolomite effected. It is interesting to note that, during the 1959 (first) campaign, dolomite consumption was 22 lb per ton. On the second campaign, after the introduction of lime powder fettling, the dolomite consumption was reduced to 3.8 lb per ton, and the overall average to date this year is 1.30 lb per ton. The protection afforded to the side walls is indicated by the phenomenal life of 1391 heats in the first period of the second campaign and 2828 heats for the second period of the same campaign ending August 4, 1961. This method of fettling has recently been extended to the hot metal arc furnaces resulting in an increase of 50 pct in side wall life. (See Table I).

Oxygen-lime injection

Oxygen for the pre-refining operation is injected into the metal through a water-cooled lance specially designed for this purpose by HOAG of Germany. The lance enters the furnace on the axis of tilt, so that it can operate while the furnace is tilted in any position. It is thermostatically controlled. Various types of nozzles have been tried but a single-nozzle oxygen/lime jet has proved highly satisfactory. These nozzles are replaceable and can be easily welded up and repaired in the event of leaks. The nozzle fins or serrations are coated with magnesite slurry for the first heat, following which slag becomes keyed into the fins and affords adequate protection when the lance is immersed into the metal bath. Oxygen is injected into the bath through the lance at 1250 to 1400 cfm.

During the trial period of lime dispensing, various mixtures of powdered lime and limestone were tried before an ideal combination was evolved. It was found that dissociation of pure ground limestone caused excessive gas off-take temperatures, whereas pure powdered lime packs in storage thus making it extremely difficult to enter into the oxygen stream. Eventually, a mixture containing 75 pct CaO and 25 pct $CaCO_3$ was adopted, this material giving efficient flow properties at a grading of $-\frac{1}{8}$ in.

The lime/limestone mixture is fed into two, 3-ton capacity dispensers from storage bunkers. It is mechanically fed into the bunkers from road transport tankers and is again pneumatically transferred into the lime dispensers which are placed on load cells. The material is metered into the lance as a recording indicator checks the amount being injected. This can be varied between 40 and 400 lb per min by a variable speed motor, again pre-set and controlled from the operators' panel on the melting shop stage.

Erosion troubles of piping leading to the lance have been overcome by using special stainless tubing for the fixed and flexible hoses.

Pre-Refining

Before adding the hot metal, the scrap portion of the heat is charged by a floor charging machine. This scrap amounts to between 10 and 25 pct of the charge weight, depending on the availability of pit scrap and silicon content of the iron; it consists of high silicon skulls, pit scrap containing up to 4.0 pct Si, and crop ends. By this means, highly siliceous scrap can be melted and recovered. One

Table II. Operating Characteristics of Pre-Refining Furnaces

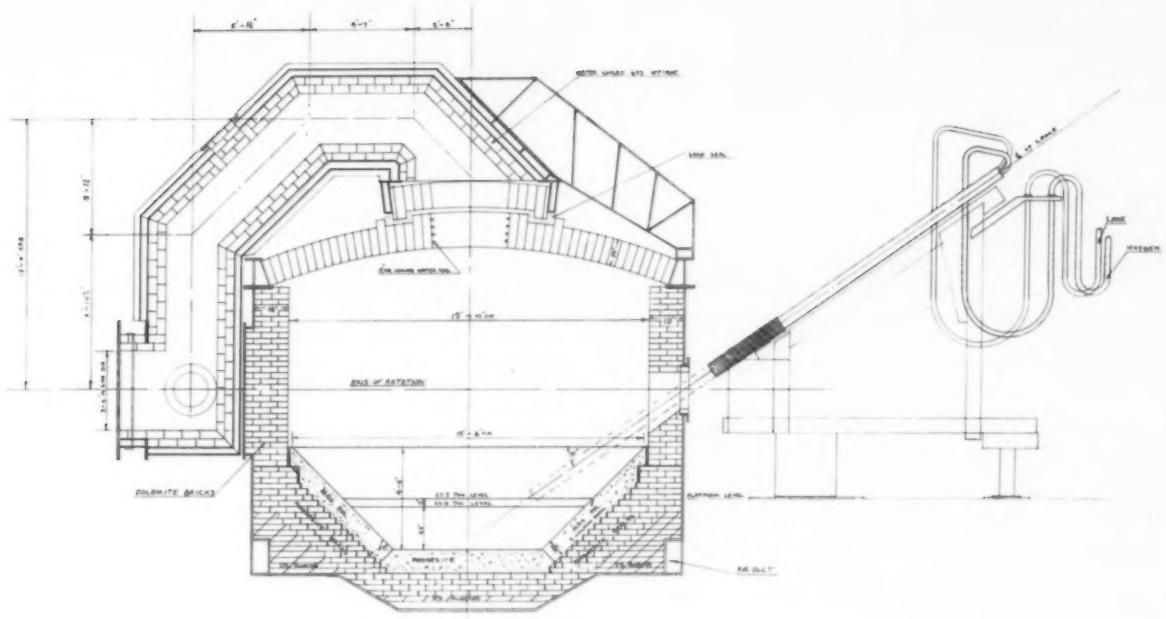
	Analysis, pct				
	C	Si	S	P	Mn
Hot Metal	3.8-4.0	0.5-1.5	0.04-0.07	0.4-1.5	0.7-1.25
Pre-Refined Metal	1.0-2.5	Tr-0.05	0.04-0.05	0.025-0.080	0.10-0.20

Total Heat Time (Charge to Tap), hr	0.75-1
O_2 per long ton of Blast Furnace Metal, cu ft	900
Scrap Melted, pct	25-30 max
Overall Efficiency of O_2 usage, pct	100+
Overall Yield of Material, pct	93
Temperature rise, °C	200+

Table III. Typical Electric Furnace Charges Using Pre-Refined Blast Furnace Material[a]

	Si-Mn					Mn-Mo					C-Mn			
Charge														
Total wt, tons	46.9					48.35					40			
Wt of Pre-Refined Metal, tons	21.05					21.5					21.9			
Pct Pre-Refined Metal	45.0					44.5					44.6			
Furnace Details														
Heat Time	3 hr 35 min					4 hr 35 min					6 hr			
Production, tph	12.2					9.54					7.45			
Electricity, units/ingot ton	344					409					436			
Oxygen, cu ft/ingot ton	215					200					240			
Metallic Yield, pct	94.0					93.1					91.5			
Analysis, pct	**C**	**Si**	**Mn**	**S**	**P**	**C**	**Mn**	**S**	**P**	**Mo**	**C**	**Mn**	**S**	**P**
Pre-Refined Metal	2.26	—	0.10	0.052	0.072	2.04	0.10	0.048	0.082	—	2.10	0.12	0.052	0.090
Furnace Melt Out	0.96	—	0.22	0.053	0.018	0.75	0.15	0.039	0.020	0.045	0.80	0.23	0.045	0.017
After Oxidizing Period	0.53	—	0.28	0.037	0.011	0.26	0.32	0.027	0.015	0.205	0.31	0.22	0.032	0.010
During Reducing Period											0.35	1.14	0.024	0.012
Final Pit Analysis	0.55	1.79	0.92	0.031	0.020	0.365	1.46	0.025	0.020	0.235	0.37	1.12	0.016	0.013

[a] All tonnages in long tons unless otherwise specified.

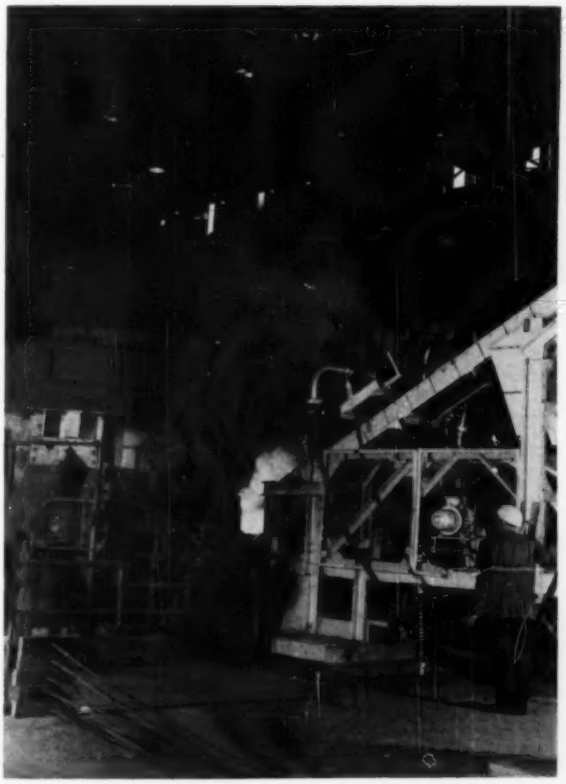


Above, Cross section of pre-refining furnace no. 2. Below, Oxygen lancing showing water-cooled lance immersed.

third of the amount of lime is added in ½ to 1½ in. lumps, and the required amount of ore is spread over the lime. From 20 to 25 tons of hot metal is then poured through a portable trough into the furnace, and the furnace pressure is checked. Oxygen is injected through a water-cooled surface lance at 600 to 800 cfm for about 3 min. This is sufficient to commence the reaction and form the slag necessary to protect the large water-cooled lance nozzle. The main lance is then lowered into the bath to a position just below the slag/metal interface, i.e. approximately 9 in. below the slag surface. The total oxygen input at this stage of the operation is approximately 1600 to 1700 cfm. Lime injection commences shortly after the main lance is lowered into the bath and continues for a predetermined period but the blow is finished with oxygen only. After the surface lance is withdrawn, and the heat is finished with the main lance.

The need for the preliminary blow with the surface lance may be debatable, but experience has shown that it is a well tried precautionary measure and ensures protection for the main lance. Failures and troubles with the main lance have occurred only when this precautionary measure has been ignored.

The total blowing time averages 20 min which can be reduced or prolonged according to the requirements of the arc furnaces. When the bath carbon is in the desired range—which varies between 2.5 and 1.25 pct according to the specification required in the finished steel—samples of metal and slag are taken, and the bath temperature is checked with the immersion pyrometer. In the higher carbon range, it is quite unnecessary to carry high bath temperatures, and rarely are these allowed to exceed 1550° to 1570°C which allows ample time for tapping and transferring to the electric furnaces. Even in the event of mechanical or other



delays, skulled ladles are a very rare occurrence, and this is a great advantage.

The pre-refined metal is used as 50 pct of the electric furnace charge; it always contains sufficient carbon to ensure adequate melt-out carbon to make final decarburization in the electric furnace (using the oxygen lance) simple and rapid. Another feature of pre-refining is that the iron content of the slag can be kept at quite a low level, making the overall metallic recovery high. As previously indicated, the furnace is fettled between heats with lime powder pneumatically injected onto the side walls, banks, and hearth of the furnace. The average blowing time is 20 min for a carbon content of 1.5 pct and 15 min for the higher carbon ranges. The oxygen efficiency is plus 100 pct and the average metallic yield 93 pct.

Operating data for pre-refining are contained in Table II.

One of the additional advantages of using the pre-refiner is its ability to absorb large-sized and awkwardly-shaped scrap. Large lumps of slaggy pit scrap cannot be melted satisfactorily in the arc furnace since they tend to cause electrode breakages, but in the pre-refining furnace they are melted easily and cheaply.

Electric steelmaking

The pre-refined metal is transferred to one of Brymbo's 40-ton electric furnaces in which the scrap has already been charged and heated. The power having been on the arc furnace for only 20 to 25 min, it is thus possible to maintain the power on the furnace while charging the hot metal; this reduces surging and facilitates smooth operation at maximum power input, thus reducing the incidence of electrode breakages.

Typical examples of hot metal heats are shown in Table III. By increasing the amount of hot metal in the charge, considerable economies in power and electrode consumption can be effected. The average electrode consumption on 50 pct hot-metal charges is 8 lb per ton. Electric power consumption ranges between 230 and 400 kw-hr per ton, depending on the amount of hot metal in the charge. Heat time using 85 pct hot metal is approximately 2 hr for a 48-ton charge consuming 230 kw-hr per ton.

One-Furnace operation

As indicated previously, this process was developed for pre-refining medium and high phosphorus iron for use in the electric arc furnaces. Blast furnace hot metal, containing up to 1.5 pct P has been pre-refined. Pre-refining has proved very suitable for this work, but it has always been recognized that, if the whole process could be carried out in the same furnace, further savings would accrue. In order to investigate this, an arc furnace fitted with a water-cooled roof fume offtake was used, and the results are most encouraging. Further economies in power and electrode consumption are being achieved, and the lowest unit consumption to date is 133 units per ton using 80 pct hot metal.

The effect of this practice on refractory consumption has not yet been fully assessed, but experience to date indicates that, providing the pre-refining of the heat is closely controlled and the highly siliceous slag removed after approximately 10 min of oxygen injection, the charge can be worked quite satisfactorily.

Unlike the Ore Refining Process, the heat is controllable, and there is less danger of sudden ejections of slag and metal during refining. It has been shown that hot metal containing up to 0.5 pct P can be satisfactorily treated and the heat finished under the normal reducing slag without risk of phosphorus reversion.

Work is continuing on this process in an arc furnace fitted with water-cooled roof off-takes. The furnace is charged with a portion of the scrap (chiefly pit scrap), and the requisite amount of lime and ore are added together with 20 tons of hot metal. Silicon and phosphorus are removed during the preliminary blowing period. The furnace is then slagged off, the remainder of the lime and scrap are charged, and the heat is finished in the normal manner.

A summary of the results achieved is shown in Table IV.

Table IV. Trial Charges of Medium Phosphorus Direct Hot Metal Heats in Arc Furnace[a]

	40 Pct Direct Hot Metal	80 Pct Hot Metal (40 pct Direct) (40 pct Pre-Refined)
Charge		
Ore, lb/ton[b]	37.0	99.7
Limestone, lb/ton	—	—
Lime, lb/ton	116.5	190.4
Fluorspar, lb/ton	6.5	4.0
Oxygen, cu ft/ton	577	1208
Electricity, units/ton	312	142
Electrodes, lb/ton	6	4
Production, tph	12	16.0

[a] 0.4-0.5 pct P.
[b] All tonnages in long tons unless otherwise specified.

Conclusions

After two years' operation, the advantages of the Hot Metal Process have been adequately proved for the production of special forgings and low alloy steels. The main advantages are:

1) Increased production per furnace unit,
2) Substantial reduction in power and electrode consumption,
3) Lower refractory costs, and
4) Substantial savings in dolomite and side wall refractories by the use of lime powder fettling.

A summary of phosphorus levels in the finished steel taken over a long period shows that 50 pct of all heats made are below 0.02 pct P and 41 pct are between 0.02 and 0.03 pct, giving a total of 91 pct below 0.03 pct. The remaining 9 pct were below 0.05 pct, 7 to 8 pct being below 0.04 pct P.

The development of the Hot Metal process stems essentially from 1950 when Brymbo was the first British steel works to make use of the technique of desiliconizing blast furnace metal in the ladle with the oxygen lance.

The new *Brymbo Process* is the logical development of this technique and now makes it possible for the arc furnace to use large quantities of molten blast furnace metal offering greater flexibility and higher availability than ever before as compared with conventional open hearths producing similar qualities. No longer is the arc furnace restricted to the use of all cold scrap or fully blown duplex metal, but blast furnace hot metal in a wide range of composition can be used with complete success.

ELECTRON PROBE

X-RAY MICROANALYSIS

Discussion of a new technique—electron probe X-ray microanalysis—which makes possible the identification and the measurement of the concentration of elements in a surface area of 1 square micron and less.

by Bani R. Banerjee

Correlating microstructures with phase equilibria provides the basic foundations of physical metallurgy; yet characterizing microscopic constituents, phases, and other regions of interest, by a complete chemical analysis of localized volumes, has evaded the metallurgist for decades.

Electron probe X-ray microanalysis is a new analytical method, where a fine electron probe striking a microconstituent excites an X-ray spectrum containing wave lengths, characteristic of the elements which make up the microconstituent. The intensities of these characteristic wave lengths are proportional to mass concentration of these elements; therefore, by dispersing this spectrum in an X-ray spectrometer and measuring the X-ray intensities, a quantitative analysis can be made of the microconstituent. Electron probe microanalysis can readily analyze a microscopic volume, 10^{-10} cu. cm., with a relative accuracy of 1 pct, and a sensitivity of 0.1 pct, for elements with atomic numbers, z = 11 to 92. These limitations are not absolute, and may be exceeded, but only with special care and techniques. Improvements are rapidly being made in techniques, and in novel methods, which will undoubtedly shift these limits in coming years.

Thus, a new chapter has been opened in metallurgical history permitting the long-sought characterizing of individual phases—such as solid solutions, transformation products, and precipitates—in multiphase alloys. Inclusions, impurities, and other dispersed material may be identified. Segregation effects caused by impurity elements, by alloying elements and by chemical reactions, which form depleted or enriched zones, around grain boundaries, near surfaces, and in and around dendrites in cast materials may be detected. Concentration gradients across diffusion boundaries of experimental diffusion couples, or incomplete diffusion gradients across an interface, commonly found in industrial applications, may be determined.

A historical perspective of the development of microanalysis shows how even a potentially significant principle may require decades before scientific concepts are reduced to practice to yield a useful tool.

The principles of X-ray spectrography were pioneered by Mosely[1] in 1913, and were formalized into a method of chemical analysis[2] by 1932. Hillier,[3] in 1943, outlined the essentials of an electron probe X-ray microanalyzer in his patent application, where demagnification by two electron lenses produced a point-electron probe, and a crystal-diffraction spectrometer and an ionization chamber measured the excited X-ray intensities. Yet, until the researches of Castaing (1951)[4], these principles were not applied to develop a practical instrument.

Electron-probe scanning, though suggested by Castaing,[4] was not added until much later[5] to rapidly obtain both concentration and distribution of an element over a surface, as in the Cambridge instrument. Many instruments emphasizing various aspects of microanalysis were constructed in the last decade, and more than half a dozen commercial electron probe X-ray microanalyzers have arrived on the world market.

The instrument

Most Electron Probe Microanalyzers consist of three essential parts:

a) An electron probe of 0.3 to 5.0 micron diameter formed by an electron source and two demagnifying lenses. The probe excites X-rays from a microvolume at variable excitation potential, generally between 20 and 30 kv.

b) A sample positioning arrangement to bring a desired microconstituent directly under the analyzing probe. This may be done light-microscopically through the use of light optics coaxial with the electron-lens system, through an external light-optical positioning jig, or through electron scanning in situ and suitably imaging the scan on a cathode-ray tube display.

The unique advantages of electron scanning lie in the pictorial display—relatable to the ordinary

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light micrograph—of the distribution of a particular element over an area, and in positioning the microconstituent with a resolution equal to or better than that possible with coaxial-light optics. However, because of the moving X-ray source, the full-focusing Rowland geometry loses its unique advantage, and is sometimes replaced (as in the Cambridge Microanalyzer) by a semi-focusing spectrometer, with some—though not serious—performance loss in terms of X-ray intensity, resolution, and peak-to-background ratio.

c) An X-ray spectrometer to measure the characteristic X-ray intensities; the spectrometer may be either of the full-focusing or semi-focusing types, employing proportional counters and electronic circuitry to provide adequate counting statistics. To decrease air attenuation in analyzing for elements with z = 12 to 22, a vacuum enclosed spectrometer is desired.

Operation

In principle, operating a microanalyzer involves simply focusing the micron-diameter electron probe on the constituent to be analyzed, and measuring the intensity of the characteristic X-ray for the element under analysis. This intensity—corrected for counter dead time and background—is proportional to mass concentration of the emitting element, relative to similarly corrected X-ray intensity measured from a pure-element reference standard. Because of the small volume of excited material in microprobe analysis, this simple proportionality of mass concentration to relative X-ray intensity is of surprisingly general validity under suitable conditions, and can readily give a relative accuracy of 1 pct.

When analyzing for elements having low atomic numbers, or operating at high kilovoltages, and when the X-ray emergence angle from the specimen is small, erors due to sample absorption tend to increase. At low concentrations of the analyzed element (less than 1 pct) a disproportionate increase in counting time is required to achieve the same accuracy, because of increased continuous X-ray background—*Bremsstrahlung*. Strong interelement effects generally arise when analyzing near-neighbor elements in the periodic table, for example in an Fe-Cr alloy the FeK_α characteristic emission can excite CrK_α fluorescent radiation. However, analytical methods have been developed to correct for specimen absorption, interelement effects, and mutual fluorescence, in addition to counter deadtime and background, so that individual calibration curves are not needed for every system analyzed. Thus, combining appropriate experimental conditions, with analytical correction methods, measured spectral intensities can be accurately converted to mass concentrations.

In a scanning microanalyzer, as the probe scans an area up to 0.5 mm square the backscattered-electron intensity detected by a scintillation counter modulates the brightness of a cathode-ray tube. Contrast in this point-for-point reproduction of the sample image depends upon: (a) surface topography of the sample, and (b) local variations in atomic number on the sample surface. Thus, the image not only has visual qualities of an oblique-incidence micrograph, but additionally reveals the mean atomic number of elements in the sample. The detailed distribution of a given element may be similarly imaged by modulating brightness on a cathode-ray tube, using the signal from the X-ray spectrometer, which receives X-rays characteristic of a single element at a given spectrometer setting.

Because of the localized nature of microanalysis, careful preparation of the sample surface is extremely important. Any technique that alters the local chemistry of structural entities must be avoided; chemical etching, and electrolytic polishing are not desirable. The best surface preparation for microanalysis is a diamond metallographic polish, although this does not reveal metallurgical features by light metallography. Thus, the scanning electron image will often reveal these features, because of surface topography or local atomic-number differences—an added advantage of scanning.

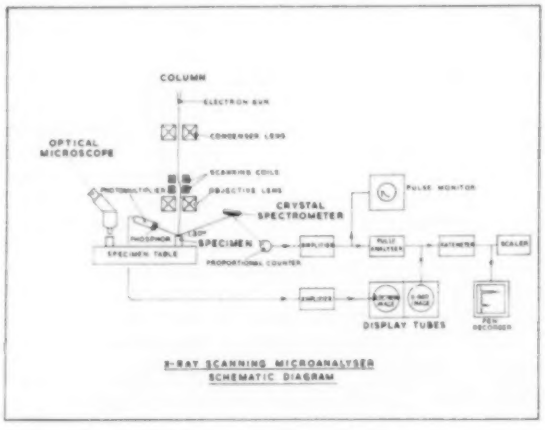
Crucible Research was one of the first in the United States to install a Cambridge Scanning Microanalyzer. With this powerful tool, many industrial metallurgical problems have been solved. Inclusions, microsegregations, selective alloy depletion from surface-chemical reactions, and matrix chemistry of alloy steels have been analyzed by microprobe techniques; composition of carbides and other dispersed phases were also determined by microprobe analysis of extraction replicas.

In the first six months of microprobe applications, many unexpected cases of microsegregation have been recorded; local concentrations on a micron scale can enormously exceed expected levels, under non-equilibrium conditions. For example, iron, occurring as an inadvertent segregate in a titanium alloy, was found locally concentrated to many times its normal percentage. Similarly, almost complete alloy-element depletion through microsegregation was observed in an alloy steel. On the other hand, partitioning of alloy elements between matrix and precipitate, subsequent to a precipitation reaction, may be readily followed by this technique; for example an alloy steel containing more than 4 pct V on the average, contained about 0.5 pct V in the matrix solid solution, after precipitation of alloy carbides.

Undoubtedly, further explorations of the detailed chemistry on a microscopic scale will yield many surprising and unexpected results, which may substantially modify present metallurgical thinking.

Future

Improvements in microanalysis, currently being attempted at various laboratories, are mainly in two directions: (a) to extend microanalysis to



X-RAY SCANNING MICROANALYSER
SCHEMATIC DIAGRAM

lower atomic-number elements, at least down to carbon (z = 6), and (b) to improve the resolution of microanalysis substantially below the present 1-micron limit.

Contrary to earlier experimental findings, absolute X-ray spectral intensities from light elements, such as carbon, seem to be comparable in magnitude, to those from heavier elements, provided the light elements are excited at appropriately low excitation potential, in the microanalyzer. However, the problem in microanalyzing light elements is in the rapidly increasing X-ray wave length with decreasing atomic numbers below about 12. While the K or L emission spectra for all elements with z from 12 to 92 lie between 0.7 Å and 10 Å; for z = 6, carbon K radiation has a wave length of 44 Å, involving more than a four fold increase. Here the problem becomes one of finding a suitable crystal to diffract or disperse radiation of this wave length. Therefore, ruled gratings may be used dispersively, or proportional counters and windowless photomultipliers may be non-dispersively used with pulse-height analysis for discriminating between different elements. Although most ruled gratings are not efficient at these wave lengths, and non-dispersive counting does not provide desired spectral resolution, the difficulties are not insurmountable.

The chief obstacles to better resolution in present-day microanalyzers are: (a) the penetration and lateral diffusion of the incident electrons in the specimen, (b) the maximum current deliverable to the probe, and (c) the aberration of the lens systems, particularly the objective lens. At the usual operating voltages of 20 to 30 kv, vertical electron penetration and lateral diffusion in a thick specimen are on the order of 1 micron. Therefore, under such conditions, making the probe diameter much smaller than 1 micron becomes of questionable value, particularly because of the attendant loss in incident intensity. However, with a thin sample, such as an extraction replica, a resolution no worse than the specimen thickness may be expected with a sufficiently small probe; electron optics for obtaining a 200 Å diameter probe have been known for decades.[6] Even with thick samples, low-excitation voltages and adjustment of electron optical factors to optimize resolution have yielded a resolution of 0.1 micron with non-dispersive analysis.

Thus, both light-element analysis, and improved resolution hold promise for the future of electron probe X-ray microanalysis. Although many instruments are now commercially available, each embodying some unique features, the next decade will undoubtedly permit consolidation of many formative ideas leading to even better instrumentation; also techniques and methods of analysis will undoubtedly be improved to establish microanalysis as a fundamental tool for correlating microstructures with phase equilibria for further advances in physical metallurgy.

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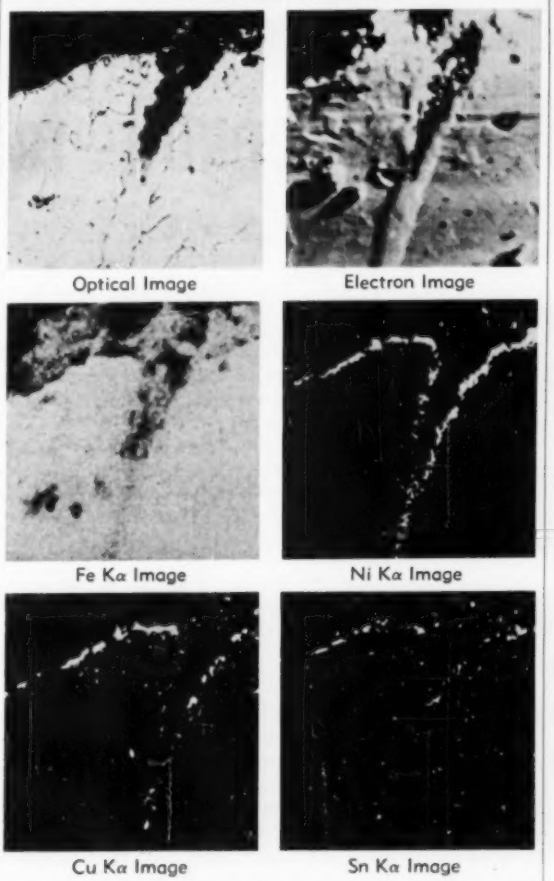
An Example of Application



300X, Reduced 33 pct for Reproduction

An example of the application of the Cambridge X-Ray Scanning Microanalyzer is shown by the above figure, supplied by S. A. Bergen, chief development engineer of Cambridge Instrument Co., London.

The optical image corresponds closely to the electron image which, however, gives more information on surface relief. The normal chemical analysis of the steel shown is 0.14 pct Ni, 0.2 pct Cu, and 0.059 pct Sn. The iron distribution can be seen to correspond to the optical and electron images. The nickel concentration, however, is much higher along the sub-scale than elsewhere, instead of being distributed evenly throughout the material. The maximum copper concentration also occurs along the sub-scale, but it is in discrete regions. Tin enrichment is associated with those regions richest in copper, but it is in lower concentrations.

It can be seen that the raised area around the crack is rich in both nickel and copper. This suggests that this region would contain material much harder than the matrix, causing relief polishing in the preparation of the sample. Microhardness tests confirm that this was the case.

These photographs display the distribution of the elements in question; the next stage is to position the probe on the points of interest and determine the concentration of these elements.

HIGH-TEMPERATURE DUCTILITY OF BORON—TREATED STEEL

Tensile samples of boron-treated and non-treated 25 Cr-20 Ni steel were fractured at varying strain rates and temperatures ranging from 1700° to 2300°F in order to obtain quantitative information on the ductility of the treated and non-treated steel.

by F. K. Bloom and E. E. Denhard, Jr.

Boron additions as small as several ten-thousandths of one percent have been observed to markedly improve the hot rolling and forging characteristics of the chromium-nickel austenitic steels[1]. Similar improvements in hot workability have also been claimed for small additions of this element to nickel base alloys[2]. This improvement in hot working characteristics is clearly the result of higher ductility of the alloys at hot working temperatures. There do not appear to have been any previous attempts to determine quantitatively the extent of this effect on hot ductility or how it is influenced by temperature or by strain rate. Nor is there any data to indicate how boron additions affect the microstructure and grain deformation process at these very high temperatures.

To obtain quantitative information on the comparative ductility of boron treated and non-treated stainless steels at hot working temperatures, tensile samples were prepared and pulled at varying strain rates and temperatures. The observations made of the fractured samples and their microstructures are the subject of this paper.

Experimental procedure

The tensile samples were prepared from bar stock processed from a commercial arc furnace heat of Type 310, 25 pct Cr-20 pct Ni stainless steel. This grade was selected because of the pronounced differences boron was noted to make in the hot rolling performance. In additions, this alloy is normally austenitic throughout the hot working range and is uncomplicated by the presence of other phases. Boron addition was obtained by adding rasorite (sodium tetraborate) to one of the ingots, while another was left untreated, thus providing two lots of steel identical in composition and melting practice except for the boron content. The analysis was: (1) Untreated—0.072 pct C, 1.90 pct Mn, 0.020 pct P, 0.019 pct S, 0.54 pct Si, 24.65 pct Cr, 19.99 pct Ni, and less than 0.0002 pct B; and (2) Treated—0.0023 pct B.

The boron content of the treated material was checked at several locations in the ingot and in the bar stock and found to be distributed uniformly. The ingots were processed by normal steel mill practice into 1 in. round, hot-rolled stock. Tensile coupons were laboratory annealed at 2300°F, ½ hour, water quenched, and machined into standard 0.505-in. diameter high temperature tensile specimens. The heat treatment was used to bring the samples to a uniform initial state and to provide a large grain size to facilitate examination of the effect of deformation on grain flow. Samples were pulled to fracture after soaking for 10 min at temperatures of 1700°, 1850°, 2000°, 2150° and 2300°F in a furnace equipped with silicon carbide elements. Temperatures were measured and controlled within the 2.5-in. gage length to ± 10°F. Samples were strained at 3, 0.4, 0.04, and 0.004 in. per in. per min. Rates were maintained by manual adjustment, using a Baldwin-Southwark Ram Pacer as a guide

Rapid heating and short soaking times were employed to minimize as much as possible deboronization of the samples. Checks made on specimens after testing showed that some deboronization had occurred on samples tested at 2300°F and strained at the lowest rates of 0.04 and 0.004 in. per in. per min. In the former case the fractured end of the tensile sample showed that the boron content was reduced to 0.0007 pct, and in the latter case to 0.0004 pct. The balance of the samples were not affected significantly.

As the specimens broke, the bottom half fell free of the machine, and was immediately quenched in

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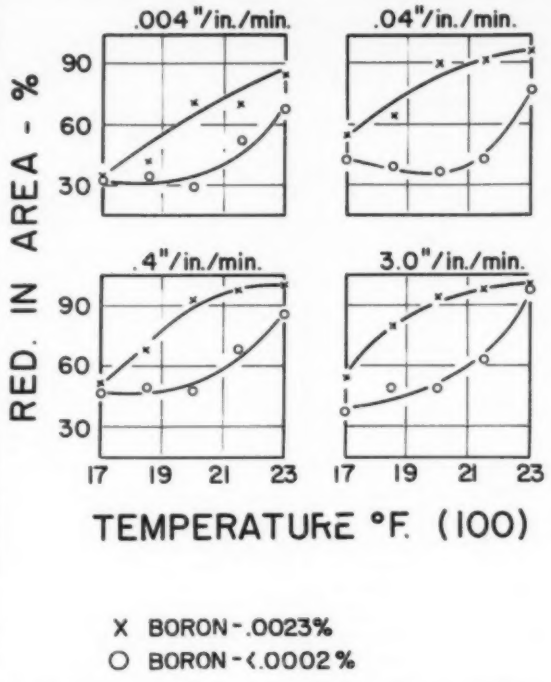

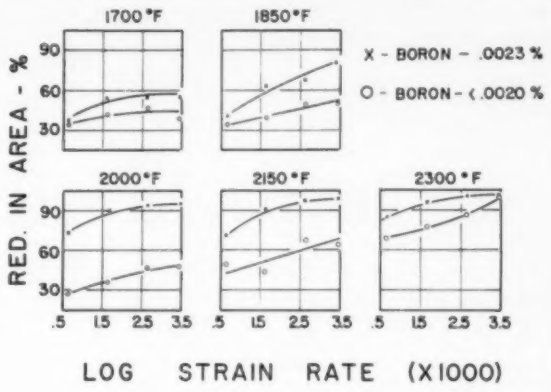

Fig. 1—Left, Ductility vs. temperature at various strain rates. Fig. 2—Above, Ductility vs. strain rate at various temperatures.

water. Longitudinal micro-examinations were made of each of these and photomicrographs were taken in a region approximately ½ in. back from the fracture.

The results of the tests are shown in Table I and in Figs. 1 and 2, which show the effect of temperature and of strain rate on reduction of area values respectively.

Discussion

Specimens that contained boron consistently showed more ductility than those without, although the degree was greatly affected by testing speed and temperature. Boron treated samples were characterized by a tapered necking, at times drawing down to a point. In contrast, untreated samples frequently broke with a flat rupture face and with extensive surface tears or cracks extending well back from the fracture. Fig. 3 illustrates typical fracture samples.

At the lower test temperatures (1700° to 1850°F) boron-treated and non-boron treated samples displayed brittle type fractures, with only a slight improvement noticeable in those samples with the boron addition. Strain rate appeared to have only a small effect in this temperature range.

The greatest difference in ductility between treated and untreated samples was in the intermediate temperature range of 2000° to 2150°F. At these temperatures, boron-treated specimens fractured with reductions in area in excess of 90 pct. Increasing strain rate became significant at these temperatures, particularly for the untreated samples.

At the highest test temperature and strain rates, boron-treated and untreated samples both dis-

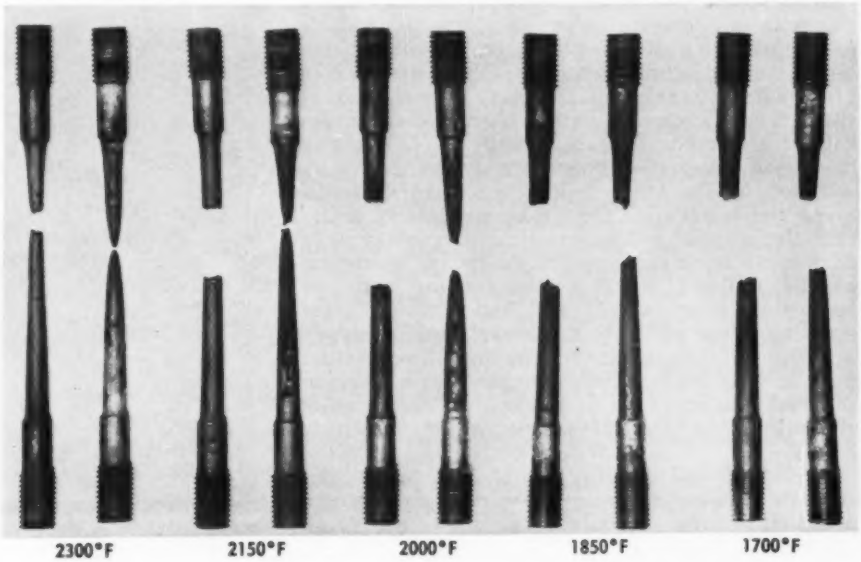

Fig. 3 — Appearance of fractured tensile samples pulled at intermediate strain rate of 0.04 in. per in. per min at temperatures noted. (Right-hand sample of each temperature group contains boron addition.)

Table 1. High-Temperature Tensile Tests on Wrought 25-20 Stainless Steel

Strain Rate	Temp, °F	Boron 0.0002 pct			Boron 0.0023 pct		
		Ult. Tens. Str. psi	pct El. 2.5 in.	pct RA	Ult. Tens. Str. psi	pct El. 2.5 in.	pct RA
3 in./in./min.	2300	5,170	84.2	98.3	5,740	95.0	100
	2150	7,025	65.0	63.4	7,225	82.4	97.5
	2000	10,250	43.8	48.5	9,750	75.0	94.5
	1850	17,150	41.5	49.5	16,400	55.7	80.2
	1700	25,500	34.6	37.5	23,150	41.0	55.0
0.4 in./in./min.	2300	3,550	78.5	85.0	3,780	93.0	100
	2150	5,100	67.8	68.0	5,670	82.0	97.5
	2000	7,550	49.0	47.0	7,440	75.0	93.5
	1850	12,200	45.3	49.2	12,750	61.0	68.3
	1700	17,450	39.0	47.3	17,350	46.0	53.1
0.04 in./in./min.	2300	2,250	88.0	77.0	2,300	87.5	95.9
	2150	3,800	41.7	43.5	3,800	90.0	91.2
	2000	5,100	35.6	36.0	4,750	71.0	90.5
	1850	8,400	35.0	39.0	8,300	59.8	64.5
	1700	15,100	32.6	42.0	14,350	43.0	55.5
.004 in./in./min.	2300	1,650	54.5	68.5	1,240	52.5	85.0
	2150	2,220	44.8	52.0	2,250	46.5	70.5
	2000	3,440	18.6	28.0	3,125	73.0	72.0
	1850	5,440	34.9	34.5	5,525	38.3	40.5
	1700	8,800	32.6	34.5	9,075	34.2	36.5

played high levels of ductility with both samples *necking-down* to a point. Increasing strain rate was particularly effective at this temperature, and the ductility of untreated samples was observed to approach treated samples as the speed of testing was increased.

Metallographic observations

Microstructural studies of the fractured samples were interesting and revealed two distinct modes of grain deformation. At 1700° and 1850°F—independent of strain rate—extension was accommodated by elongation of the primary austenite grains which were of equal size in both materials. This simple process was characteristic of treated and untreated samples. Carbide precipitation was both intergranular and intragranular at these temperatures and was noticeably heavier in the boron treated specimens. Fracture initiated at grain boundaries located at right angles to the direction of stressing or at triple points, and followed intergranular paths. Fig. 4 shows typical examples.

At 2000°F, a striking difference in microstructures was evident. Samples without the boron addition continued to strain primarily by elongation of the original austenitic grains. At the same time, some small degree of sub-grain formation also appeared which was more extensive at the higher strain rates. Fracture occurred at the boundaries of the primary austenite grains. On the other hand, boron treated samples were almost completely free of primary intergranular cracking. Instead, each of the primary austenite grains, dependent on strain rate, fragmented in grain boundary regions and developed sub-grains. These new grains commonly initiated at the triple points and then extended along the boundaries until they completely encircled the original grains, resulting in a network of completely equiaxed crystals. At this temperature, samples pulled at the slowest strain rate, appeared completely recrystallized and had a larger grain size than those pulled at the faster rates—probably a result of longer time at temperature. The fracture path in these recrystallized samples was difficult to pinpoint, but appeared to follow the boundaries of the sub-grains. Typical structures are shown in Fig. 5.

At 2150°F and a strain rate of 3 in. per in. per min, the non-boron treated specimens still showed a structure only partially fragmented, but at all other strain rates at 2150°F and in all cases at 2300°F the specimens were completely recrystallized into a fully equiaxed structure.

The boron treated specimens were substantially similar in appearance to the untreated samples and exhibited completely equiaxed structures even in the sample which was strained at 3 in. per in. per min and which elongated 95 pct before fracture. Fracture paths at failure in both materials appeared to be intergranular and to initiate from non-metallic inclusions. Fig. 6 illustrates the typical equiaxed structure of samples fractured at 2300°F.

Conclusions

The results of this investigation have confirmed in a quantitative manner the earlier commercial observation that boron profoundly alters the duc-

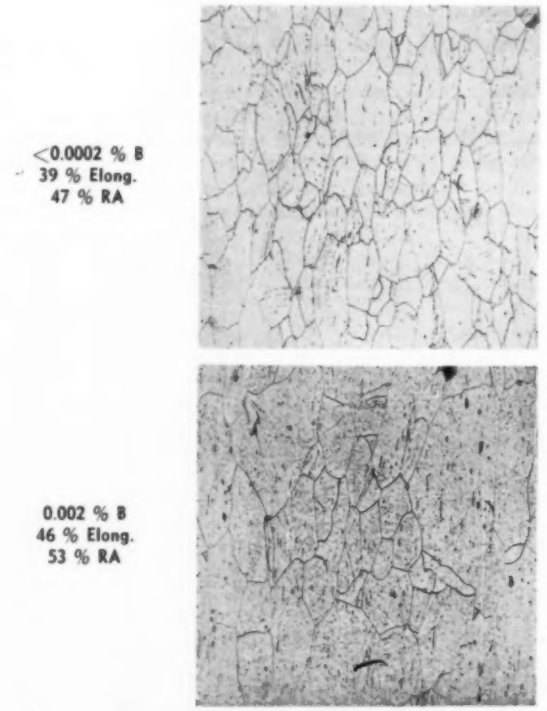

Fig. 4. Microstructures of tensile samples pulled at 0.4 in. per in. per min at 1700°F, Electrolytic 50-pct HNO_3 etch, 50X. Reduced approx 50 pct for reproduction.

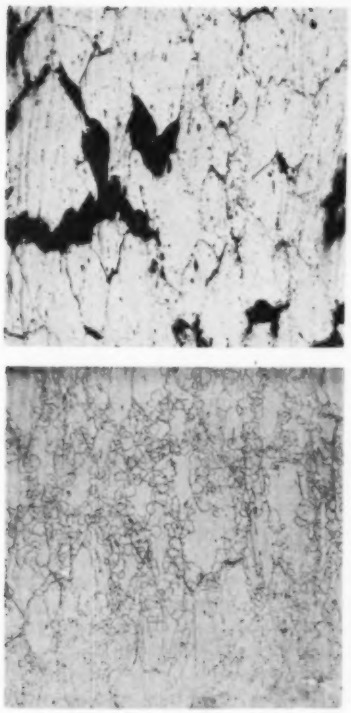

Fig. 5—Microstructures of tensile samples pulled at 3 in. per in. per min at 2000°F, Electrolytic 50-pct HNO_3 etch, 50X. Reduced approx 50 pct for reproduction.

tility of austenitic stainless steels in the hot-working temperature range. The effect is most marked from 2000° to 2150°F, and becomes negligible at 2300°F, particularly at high strain rates where both treated and untreated materials are highly plastic.

Two rather distinct modes of deformation are present depending primarily on temperature and to a lesser degree on strain rate. At the lower temperatures the original austenite grains appear simply to elongate until they part at the boundaries.

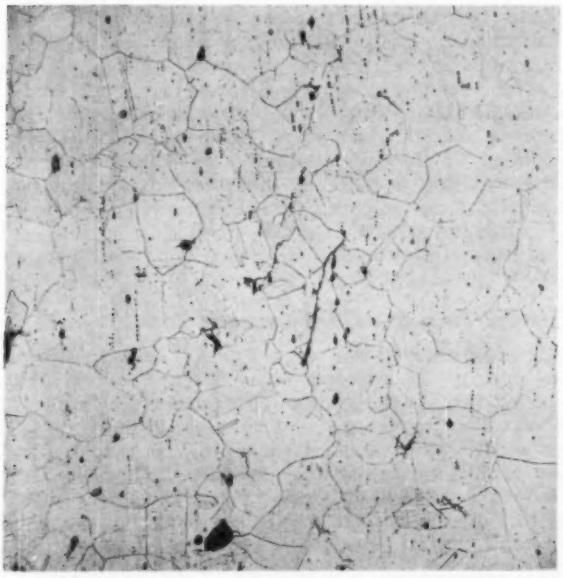

Fig. 6—Microstructure of tensile sample pulled at 0.4 in. per in. per min at 2300°F, Electrolytic 50-pct HNO_3 etch, 50X. Reduced approx 8 pct for reproduction.

At 2000°F, the temperature at which carbides begin to go in solution, the mode of deformation begins to change to one where deformation is accompanied by the appearance of equiaxed sub-grains which form along the original boundary and gradually become more numerous until they encompass the entire grain. As the temperature increases, or as the strain rate decreases (i.e. with longer time at temperature) these sub-grains grow larger in size and remain completely equiaxed, even at the highest deformations and strain rates. It can only be concluded from this that the grain boundaries are able to move at velocities greater than the rate at which they are deformed by straining.

The role which boron plays in increasing the amount of strain which the material will undergo before fracture is far from obvious. It has been suggested that its effect on ductility in rupture tests at much lower temperatures is due to the effect which it exerts on the composition and structure of grain boundary carbides[3]. This theory might be applied to explain the small improvement in ductility observed in our tests at 1700° and 1850°F, but it is hardly applicable at 2000° and 2150°F where carbides are largely or completely in solution and yet where an even larger effect on ductility is observed.

At these temperatures, boron seems to act to keep primary grain boundary fracture from occurring until the mechanism of sub-grain formation occurs, and which when it does, boron greatly increases the ability of the material to deform. Very careful examination of samples at high magnifications has suggested that this primary grain boundary cracking begins with the formation of tiny voids which coalesce into larger cracks and which in turn extend along the boundaries. The appearance of these voids is somewhat similar to those which have been found in non-ferrous materials and attributed by some to the condensation of lattice vacancies[4, 5]. If this theory is applicable, boron must act in some way to inhibit the motion of vacancies to the boundary or their nucleation into voids. Studies of the effect of boron on hardenability of low alloy steels indicates that this element is strongly concentrated in the vicinity of the austenite boundaries[6], so it is at least not surprising that its influence at high temperatures is again on a phenomenon that initiates at this point.

At 2300°F, where the mechanism of sub-grain formation and rapid grain growth has completely taken over, the effect of boron becomes quite small. At these temperatures grain boundary motion under the influence of strain and thermal motion is so rapid that all vestiges of the original grain structure are quickly erased and with them apparently the beneficial effects of boron.

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CALCULATING OXYGEN CONTENTS IN MOLTEN STAINLESS STEELS

This paper discusses the use of thermodynamics to calculate oxygen concentrations in molten stainless steel baths, presents a calculation technique, and demonstrates its application to actual production heats of stainless steel.

by S. Ramachandran, R. A. Walsh, and J. C. Fulton

For about 30 years there has been a continuous effort directed toward the application of physical chemistry to steelmaking. While the benefits derived from numerous developments have been most rewarding, there continues to be a need for further progress in the use of thermodynamics to meet the more stringent requirements for cleaner steel. Residual oxygen content is one of the most important factors which determines the inclusion content of stainless steels. For this reason, electric furnace practices have been developed around this important consideration. Thus, the process may differ in the nature of charge materials and source of oxygen for elimination of carbon, but it is universal to have a finishing period at the end of the heat cycle to deoxidize the bath. Although this feature of electric furnace practice has been in use for many years, it has only been in recent years that fundamental information has been published concerning the thermodynamics of alloying elements which are present in the finishing period of the more common stainless steels.

In order to understand the important factors in formation of non-metallics in stainless steel, a long range program was started at Allegheny Ludlum Steel Corp. several years ago to apply thermodynamics to finishing period of stainless melting. A previous report on some of the results from this program showed that refractory erosion and contamination could account for only a maximum of 15 pct of all inclusions found in straight chromium and chromium-nickel stainless steels.[1] Along with and following the study of inclusions from refractories, an analysis was made of the oxygen content as it relates to the chemistry and temperature of the bath. This paper discusses the use of thermodynamics to calculate oxygen concentrations in molten stainless steel baths. The calculated values are compared with actual analyses to demonstrate the accuracy or utility of the method. Revisions have been made in some of the thermodynamic data compared to previous publication of this work.[2] The changes take into account recent modifications of the free energy of silica and interaction parameters for silicon.[3,4] Some detailed examples and all tabular data have been excluded from this report. Those interested in such information should consult the previous presentation of this subject.[2]

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Before any attempt at mathematical analysis could be made it was necessary to determine whether equilibrium was attained with respect to oxygen during electric furnace melting of stainless steel. For this purpose, 16 heats of 304 stainless steel which had been melted in 10-ton arc furnaces were sampled extensively for oxygen and inclusion content throughout the various stages of melting. Examination of the data indicated that after the bath composition was adjusted and the final deoxidation addition was made, the oxygen and inclusion contents of the bath tended to approach a constant value. The most significant correlations that could be found were between oxygen and inclusion contents, and the time elapsed from the addition of ferrosilicon to tap. These data are plotted in Figs. 1 and 2. While there is some scatter in these data, it should be noted that for Fig. 1, rho (coefficient of correlation) of 0.443 indicates significance at the 10 pct level for the curvilinear relation. Likewise for Fig. 2, rho of 0.508 corresponds to significance at the 5 pct level. Obviously, the scatter in these data can be expected to be due to the different tap temperatures and chemistries for the individual heats.

The trend to a steady state oxygen content indicates that the process, when functioning properly, approaches a state of true or quasi-equilibrium. This implies that in order to produce clean steels, it is necessary not only to insure that equilibrium is reached, but also to insure that the equilibrium value is controlled at a low level by judicious adjustment of the pertinent melt variables. Thus, it appeared that equilibrium considerations could be applied to the finishing period in commercial steel melting, and that it might be possible to develop a thermodynamic model to determine equilibrium oxygen concentrations.

Controlling deoxidation reaction

Having reached the stage where it appeared that the melting of stainless steel in electric furnaces obeyed some equilibrium with respect to oxygen, it was then necessary to develop a basis or model on which calculations of the oxygen content could be made. Slag composition was studied, especially since it was known to play a major role in open-hearth chemistry. All attempts to correlate oxygen contents of the metal with this variable were unsuccessful in that no quantitative means of representing the problem could be evolved. It was concluded that a refining slag acts primarily as an inert blanket with respect to oxygen. This statement in no way detracts from the fact that slags

are vital to electric furnace melting of stainless steel in relation to: (1) control of temperature, (2) desulfurization, and (3) addition of deoxidizers. In the latter case, the slag can be considered as a vehicle which feeds deoxidizers, such as aluminum, to the bath over a more extended period than would be easily attainable by other techniques. The net effect of slag deoxidation appears to be one of accelerating the approach to an equilibrium defined by other variables.

Admitting that slags were not in control of the oxygen content of the bath also supports the elimination of ambient atmosphere as being a strong influence. Direct contact of air and liquid metal could not be the controlling feature since this would oxidize most of the alloying elements and the iron itself.

Having eliminated these two possibilities, selection of factors controlling the deoxidation reaction was directed toward the more obvious variables of metal chemistry and inclusion composition. The importance of metal chemistry was immediately rationalized on the basis of theory and practice. Numerous laboratory studies have contributed to the establishment of the influence of various elements on the solubility and activity of oxygen in liquid steel. A comparable number of reports exist which relate practice to optimum quality; however, only a few of the more pertinent references will be mentioned.

Chipman and Elliott have recently reviewed work on the thermodynamics of electric furnace steelmaking.[5] This report provides quantitative data on solubilities, activities, and mechanisms of various reactions. The scope of their treatment of thermodynamics is quite broad, indicating that much information has been published on the subject. It is then appropriate to recall the work of Herty et al in which it was demonstrated that Mn and Si were jointly responsible for the cleanliness of low carbon steels.[6] This work was corroborated and expanded on a laboratory basis by Hilty and Crafts, who established more precisely the influence of manganese on silicon deoxidation.[7] More recently, Shields has shown that cleaner steel could be produced during melting in electric furnaces if a certain silicon level was maintained in the bath of straight chromium steel (410) for a specified time interval prior to tap.[8] In summary, it appeared that there was no question that metal chemistry was the main source of influence, but at the same time there was no published method for predicting oxygen contents of stainless steel on this basis.

If bath compositions were to be used, it could work only in combination with some clearly defined oxide phase. A review of the composition of numerous inclusion extracts revealed a consistency in the presence of SiO_2, MnO, Al_2O_3, and TiO_2. It was realized that the deoxidation products found in solidified samples did not accurately represent the compositions that occurred at steelmaking temperatures, but they could be used as a guide to the active constituents. It was generally found that the inclusions in stainless steels contained: SiO_2, MnO, Al_2O_3, TiO_2, FeO, Cr_2O_3, CaO, and MgO. Usually, CaO and MgO were present in small amounts, corresponding to possible slag or bottom refractory contamination; however, they were not part of a repetitive and dominant group of oxides. FeO varied from 0.10 to 5.0 wt pct, and Cr_2O_3 varied from 0.5 to 12.0 wt pct. Although FeO and Cr_2O_3 frequently approached concentration ranges where they could definitely influence the oxygen potential, they were excluded. First of all, it is well known that when permitted to react thoroughly with one another, silicon in the bath will reduce FeO and Cr_2O_3 to very low values. Secondly, the analytical accuracy of the composition of very small particles, such as inclusion extracts, did not seem to be sufficiently reliable to warrant placing too much emphasis on the concentration of these two oxides. This left the first four named oxides to be considered as critical components of the deoxidation product.

Screening calculations were made to determine which of the four reactions leading to the formation of SiO_2, MnO, Al_2O_3, or TiO_2 could logically be used to estimate oxygen contents in molten stainless steel. MnO was immediately excluded due to its obviously weaker deoxidizing power than the other three oxides. For these calculations, it was assumed that the three other oxides were alternatively pres-

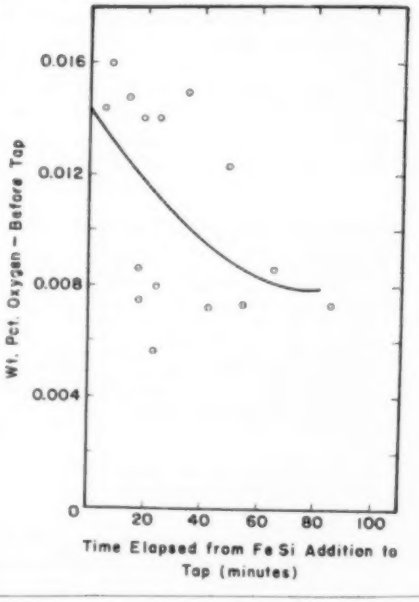
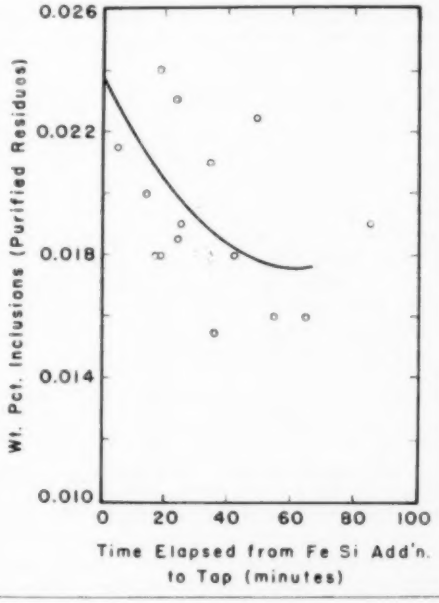


Fig. 1—Left, Relationship between the weight percent oxygen and the time elapsed from final silicon addition to tap in 10-ton electric furnace heats of 304 stainless steel.

Fig. 2—Right, Relationship between the weight percent inclusions in step-down tests and the time elapsed from final silicon addition to tap in 10-ton electric furnace, step-down tests machined from 2.75-in. square bar.



ent at unit activity. It turned out that the SiO_2 reaction was the most appropriate choice in that it predicted oxygen contents more closely related to those encountered. However, it was recognized from the calculation that some provision should also be made to decrease the activity of silica to less than unity, allowing for the dilution effect of the other three oxides. Thus, the controlling reaction can be written:

$$\underline{Si} + 2\underline{O} = (SiO_2); K = \frac{a_{SiO_2}}{a_{Si}\, a_O^2} \qquad [1]$$

Activities in the metal phase

Since stainless steel baths contain many alloying elements, and it was known that these elements influence the activity of one another, it was necessary to estimate this interaction. For dilute solutions, Wagner has shown that when a solvent A contains a number of solute elements: B, C, D, etc., the activity of an element such as B can be calculated by the equation:[11]

$$a_B = f_B\,[\%\ B] \qquad [2]$$

where [% B] denotes the concentration of B in wt pct and f_B represents the activity coefficient, given by:

$$\log f_B = e_B^B\,[\%\ B] + e_B^C\,[\%\ C] + e_B^D\,[\%\ D] + \text{- - - -} \qquad [3]$$

In equation [3], e_B^C is defined as the interaction parameter for the influence of element C on the activity coefficient of element B. The interaction parameter is defined mathematically as:

$$e_B^C = \frac{\partial \log f_C}{\partial\ \%\ B} \qquad [4]$$

It will be noted that e_B^C can be obtained directly from plots of log f vs. composition. In cases where the relation is not linear, the combined effect of various alloying elements on the activity of any particular element must be estimated by a technique of adding the individual coefficients graphically developed by Sherman and Chipman.[10]

By way of example of equation [3], we can write the relation for the activity coefficient of silicon in 430 stainless. It would have the following form:

$$\log f_{Si} = e_{Si}^{Al}\,[\%\ Al] + e_{Si}^{C}\,[\%\ C] + e_{Si}^{N}\,[\%\ N] + e_{Si}^{Ni}\,[\%\ Ni] + e_{Si}^{P}\,[\%\ P] + e_{Si}^{S}\,[\%\ S] + e_{Si}^{O}\,[\%\ O] + \log f_{Si}^{Si} \qquad [5]$$

The use of interaction parameters e for all terms except the last in equation [5] results from the fact that all other elements have a linear relation for log f vs. composition in the range of interest. The use of the log f_{Si}^{Si} term means that the relation is curvilinear and that a nonlinear solution is required

The equation for log f_O would be:

$$\log f_O = e_O^{Mo}\,[\%\ Mo] + e_O^{N}\,[\%\ N] + e_O^{Ni}\,[\%\ Ni] + e_O^{P}\,[\%\ P] + e_O^{Al}\,[\%\ Al] + e_O^{Cr}\,[\%\ Cr] + e_O^{O}\,[\%\ O] + e_O^{C}\,[\%\ C] + e_O^{Cu}\,[\%\ Cu] + e_O^{S}\,[\%\ S] + e_O^{Si}\,[\%\ Si] + e_O^{Ti}\,[\%\ Ti] + e_O^{O}\,[\%\ O] \qquad [6]$$

Equations [5] and [6] take into account the influence of major and minor elements in this alloy to the extent that the information is now available. Complete examples of these calculations were given in the original presentation of this work.[8] Returning to equation [1], we can note that:

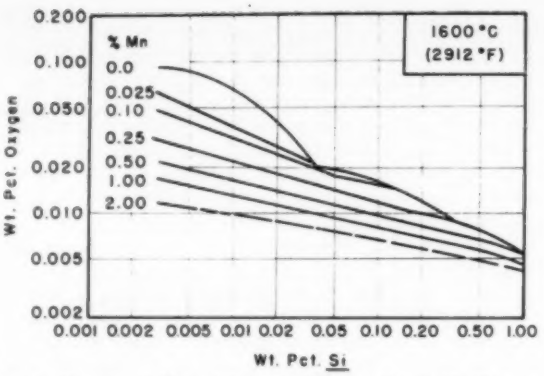


Fig. 3—Oxygen solubility data for 1600°C in the Fe-Mn-Si-O system. (Hilty and Crafts[7])

$$a_{Si} = f_{Si}\,[\%\ Si] \qquad [7]$$

$$a_O = f_O\,[\%\ O] \qquad [8]$$

Thus, from equations [5] and [6] we can calculate the required activity coefficients to multiply the respective concentrations to get a_{Si} and a_O. With a_{Si} and a_O, it would be possible to calculate a_{SiO_2} from equation [1]. It would be more useful, however, to have an independent means of calculating the activity of silicon and silica so that equation [1] could be used to estimate oxygen activities. In this way, wt pct oxygen values could be obtained. This type of solution will be discussed later.

Table I shows the existing data on interaction parameters that are pertinent to calculation of activities in straight chromium and chromium-nickel steels. Most of these data were taken from a preprinted chapter of the book: *Electric Furnace Steelmaking*.[8] In stainless steel, all the elements except chromium and nickel are present as dilute solutions in liquid iron. The effects of both chromium and nickel on oxygen have been measured up to rather high concentrations. The parameter e_O^{Ni} is constant up to at least 25 wt pct Ni, but the curve of log f_O^{Cr} vs. [% Cr] becomes slightly curved above 10 wt pct. Since the range of chromium in this work was restricted, it was possible to use an approximation which assumed linearity for the limited ranges

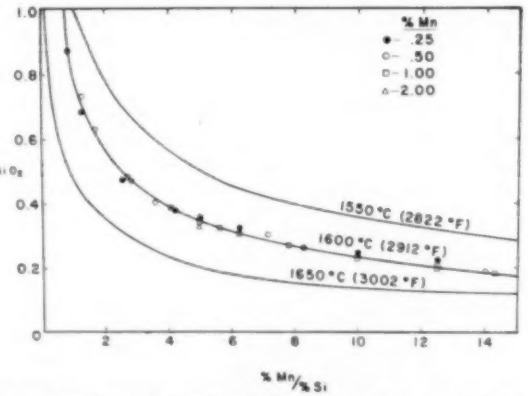


Fig. 4—Correlation of oxygen solubility data of Hilty and Crafts[7] in terms of activity of silica and the weight percent ratio of manganese to silicon.

Table I. Interaction Parameters e_B^C for Element C on the Activity Coefficient of Element B in Stainless Steel at 1600°C[5]

Component C	Component B			
	Si	Al	Ti	O
Al	0.0624	0.048	—	−0.35
C	0.243	0.107	—	−0.13
N	0.093	0.005	−2.15	0.057
Ni	0.005	—	—	0.006
P	0.086	—	—	0.070
S	0.057	0.049	—	−0.091
O	[c]	−0.59	−0.56	−0.20
Si	[d]	0.060	—	−0.02[e]
Ti	—	—	0.046	−0.187
Mo	—	—	—	0.0035
Cr[a]	—	—	—	−0.041
Cr[b]	—	—	—	−0.035
Cu	—	—	—	−0.009

[a] $e_O^{Cr} = -0.041$ for 12.0 to 13.0 pct Cr.
[b] $e_O^{Cr} = -0.035$ for 16.5 to 20.0 pct Cr.
[c] $e_{Si}^{O} = -0.877\, e_{Si}^{Si} = -0.877\left(\frac{3910}{T(°K)} - 1.77\right)$.
[d] $e_{Si}^{Si} = \frac{3910}{T(°K)} - 1.77$.[4]
[e] $e_O^{Si} = -0.02$. An empirical constant for pct Si *equivalent* to greater than 2 wt pct in stainless steel; see text.

given in Table I. This approximation permits algebraic addition of the interaction effects of all elements except silicon with negligible error.

The factor for e_O^{Si} in stainless steel is much smaller than the value of $e_O^{Si} = -0.16$ for the Fe-Si-O.[4] The need for a different value was apparent when the interaction of chromium on oxygen was taken into account. Above 12 wt pct Cr, the equivalent silicon concentration is slightly greater than 2 wt pct. On the other hand, the data in the Fe-Si-O system have recently been reviewed to limit its validity to 2 wt pct Si.[4] This meant that the data had to be extrapolated, but it was apparent that a linear extension would not suffice. Detailed analysis of several heats containing essentially no aluminum and titanium indicated that the slope of the curve should be about −0.02 beyond 2 wt pct Si. Stating e_O^{Si} in this fashion is based on an origin at log $f_O = -0.32$ and wt pct Si = 2. It is expected that this adjustment is due to either the diminishing influence of silicon on oxygen at higher concentration, or the unknown interaction of chromium and silicon. The fact that silica activity (and, therefore, silicon content of the metal) can decrease the solubility of oxygen in iron-chromium melts containing 12 to 30 wt pct Cr has been reported by Hilty, Rassbach, and Crafts.[11] This observation is in direct support of the conclusion by Shields, who related effective silicon deoxidation to cleaner stainless steel.[8] More laboratory data on this subject are definitely indicated.

Activities in the inclusion phase

The preceding section outlined a method for calculating the activity of silicon in the metal. If a corresponding value can be assigned to the activity of silica, it will be possible to calculate the activity of oxygen from equation [8]. The oxygen content can then be calculated in wt pct and compared with actual determinations. The utility of this approach appears to be quite broad when considered in connection with evaluation of the effectiveness of various practice changes or as a control tool for the melting process. An empirical method for calculating silica activities from metal chemistries was developed from the data of Hilty and Crafts.[7] We shall briefly review the problem and the solution.

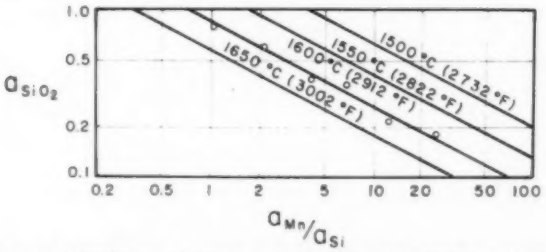


Fig. 5—Correlation of activity of silica vs. the activity ratio of manganese to silicon in the Fe-Mn-Si-O system; note log-log scale.

Fig. 3 shows a summary of the data on the solubility of oxygen in iron in the presence of manganese and silicon. An alternative plot of these data in terms of silica activities and the ratio of wt pct Mn to wt pct Si is shown in Fig. 4 using linear axes. For the sake of simplicity, only the interpolated data for 1600°C are plotted, but dashed curves are presented to show the relative position of curves for other temperatures. Silica activities were calculated with the equilibrium constant in equation [1] in conjunction with the solubility data of Hilty and Crafts[7], and appropriate activity coefficients for the Fe-Mn-Si-O system.[5] The interaction parameters in Table I would all be correct for this work except e_O^{Si} which has been modified to apply specifically to stainless steel. The extrapolation of e_O^{Si} was discussed above in connection with Table I.

The analysis shown in Fig. 4 indicates that the activity of silica in the deoxidation product is directly related to the ratio of wt pct Mn to Si. It also demonstrates that the range of application (0 to 2 pct Mn and 0 to 1 pct Si) of the result is quite broad. Although this solution would have been sufficient to enable us to calculate oxygen contents, another solution was recognized which was more convenient to use. It was noted that if the wt pct ratio for manganese to silicon was replaced by an activity ratio for these two elements, the data could be represented by a straight line on a log-log plot as shown in Fig. 5.

A similar series of graphs were prepared for the Fe-Al-Si-O system. It was found that the data could be correlated on the basis of activity of silica vs. wt pct Al to Si. Only the final relationship for activity of silica vs. the ratio of activity of manganese to silicon has been shown in Fig. 6. Since there was virtually no temperature coefficient for the range of 1500° to 1650°C (2822°-3002°F), the data were represented by one curve. These calculations were based on another study of deoxidation by Hilty and Crafts.[12] The method of calculation was similar to that for the Fe-Mn-Si-O system.

Another relation of comparable nature could be expected between the activity of silica and titanium. Since the necessary laboratory data were not available, this effect was estimated using several carefully selected commercial heats containing nominal residuals of titanium in stainless steel. The plot in Fig. 7 shows the relation calculated for titanium. The method of determining these curves depended upon the assumption that MnO, Al_2O_3, and TiO_2 were the only oxides with large effects in modifying the activity of silica. First, an ultimate silica activity was calculated from equation [1]. The problem was then approached from the other end by calculating a silica activity corresponding to the manganese to silicon ratio in Fig. 5. This estimate of the silica activity was then modified (decreased)

according to the aluminum-silicon effect shown in Fig. 6. The difference obtained by subtracting the ultimate silica activity from the equivalent (intermediate) value deduced on the basis of manganese and aluminum was attributed to titanium. A series of such values were calculated for various temperatures and activity ratios of titanium to silicon to generate the curves shown in Fig. 7.

It is worth noting that in the process of making the calculations for titanium, it might appear that a gross assumption was made when all of the difference between the ultimate silica activity and the equivalent silica activity (after modification by manganese and aluminum) was assigned to titanium. However, the support of the assumption lies in the utility of the correlation obtained. The utility of the technique will become more apparent from Fig. 9. Bridging this final gap in the lack of directly useful data on the effect of titanium was the last important obstacle to complete solution to the problem.

Thermodynamic model

To aid in describing the thermodynamic model and calculation technique, schematic diagrams have been developed for these two aspects of the problem. The thermodynamic model has been depicted in Fig. 8. Two examples were chosen for approximate compositions encountered in 430 stainless. The analyses shown emphasize that titanium and aluminum contents of the metal are small, but that they have a direct relation to the corresponding TiO_2 and Al_2O_3 contents. It would be difficult to pinpoint the precise inclusion analysis in equilibrium with the molten metal at steelmaking temperatures, because the composition can change with temperature. There could be literally any quantity of resident inclusions present at the steelmaking temperature which were characteristic of the existing equilibrium. However, the dissolved oxygen which would be precipitated when a sample was cooled to room temperature would be influenced by mass action effects. There is no quantitative means of predicting how this compositional variation would change the bulk inclusion analysis. In production of cleaner steels, it is necessary to minimize total oxygen. For this purpose, steelmaking practices are designed to eliminate resident inclusions. This again adds to the difficulty of identifying the high temperature phase.

We shall now review the calculation technique, and then demonstrate its application to actual production heats of stainless steel. Returning to equation [1], and expanding the denominator in terms of activity coefficients and weight percents we have:

$$K = \frac{a_{SiO_2}}{f_{Si}\,[\%\ Si]\,f_O^2\,[\%\ O]^2} \qquad [9]$$

The two activity coefficients can be calculated directly from equations [5] and [6], neglecting the terms multiplied by wt pct oxygen, since they will be very small relative to the other terms. Wt pct Si, of course, would be known from the heat analysis. Thus, if we can estimate the activity of silica, we have only one unknown remaining, [% O], which can be calculated from equation [9].

The method used to determine silica activities depends upon the additivity of a series of *equivalent* silica activities as related to activity ratios for the metallic phase. A schematic diagram of the graphical solution is shown in Fig. 9. This plot contains

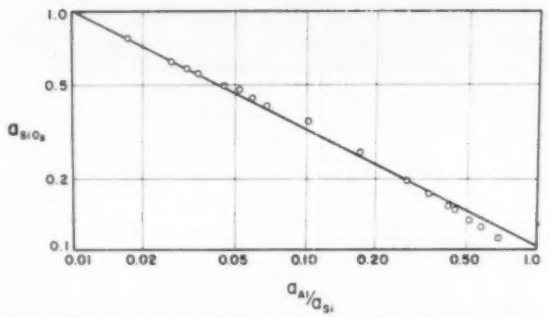


Fig. 6—Correlation of activity of silica vs. the activity ratio of aluminum to silicon in the Fe-Al-Si-O system for temperature range 1500° to 1650°C; note log-log scale. (Based on data of Hilty and Crafts.[7])

accurate reproductions of silica activities at 1600°C from Figs. 5, 6, and 7. The use of the graphs proceeds from point A where a value of 2 has been assumed for a_{Mn}/a_{Si}. The silica activity (0.20) corresponding to the location of B is then transposed to the left to C on the aluminum curve. It is then decreased by moving along the aluminum curve by a distance equal to the a_{Al}/a_{Si} value (0.7) to point D. The equivalent silica activity (0.10) is again transposed to the left to point E on the titanium curve and decreased by the a_{Ti}/a_{Si} value (0.014) to point F. This gives a completely compensated silica activity of 0.035.

Where initial a_{Mn}/a_{Si} ratios were encountered which were smaller than the a_{Mn}/a_{Si} value for $a_{SiO_2} = 1$, a proportion

$$\left(\frac{a_{Mn}}{a_{Si}}\right)_{actual} \Big/ \left(\frac{a_{Mn}}{a_{Si}}\right)_{a_{SiO_2}=1}$$

was calculated. This proportion was then used to transpose to a position below the point where $a_{SiO_2} = 1$ for the aluminum curve. The appropriate aluminum to silicon activity ratio was then added to move toward the actual curve. If the horizontal movement to the right led to values on the aluminum curve, then correction for titanium proceeded normally. Otherwise, another proportion was calculated relative to the aluminum curve in Fig. 9 and the correction was applied for titanium.

The model for making such calculations was programmed on a Royal McBee LGP 30 computer which performed each calculation in 34 sec. Fig. 10 has been prepared to demonstrate the use of the model on routine production heats of stainless steel. This curve shows the observed oxygen contents as determined by vacuum fusion analysis plotted against calculated oxygen contents. The 168 values represent a cross section of 10, 25, 50, and 65 ton heats of 410, 430, 301, 302, and 304 stainless steels. The predictability of the method is borne out by the

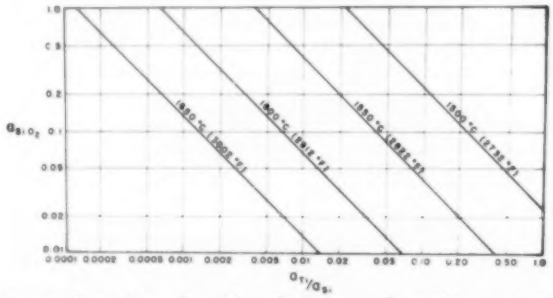
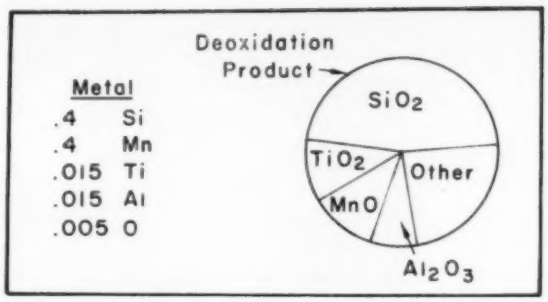


Fig. 7—Correlation of activity of silica vs. the activity ratio of titanium to silicon calculated from thermodynamic data for stainless steel.



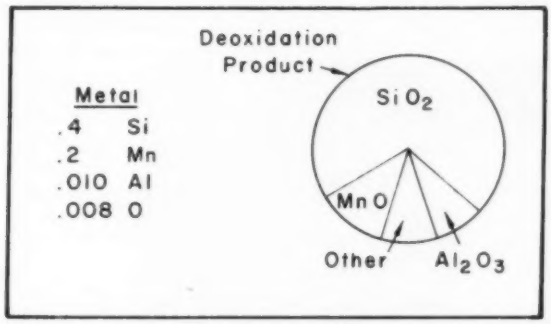


Fig. 8—Schematic representations of the thermodynamic model for two metal and deoxidation product analyses of 430 stainless.

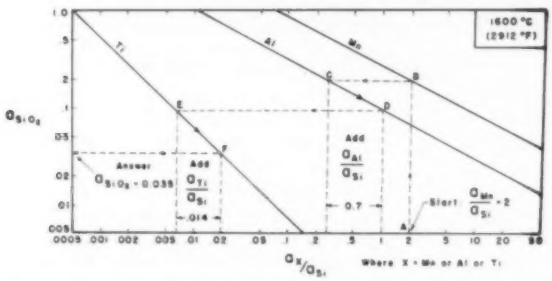


Fig. 9—Schematic diagram showing the sequence used for graphical determination of activity of silica from knowledge of the activity ratio of manganese to silicon.

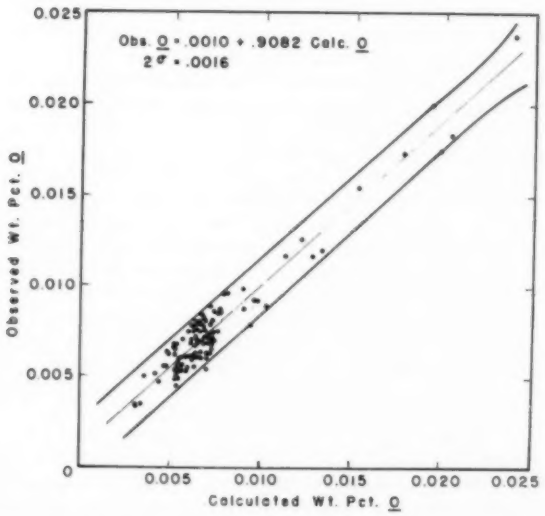


Fig. 10—Comparison of 168 calculated and observed oxygen contents for various stainless steels.

2-sigma value of ± 0.0016. Since this value approaches the analytical accuracy of oxygen analyses in the greater part of the range, it would appear that most of the important factors relative to calculating oxygen contents have been adequately represented in the solution. This conclusion is supported by the fact that the coefficient of linear correlation, R = 0.9703, is significant at the 0.1 pct level.

Conclusions

Based on the foregoing, the following observations and conclusions can be drawn:

1) A method for accurately predicting the equilibrium oxygen content of stainless steel melts has been developed from thermodynamic considerations and assumptions. Oxygen values predicted by this method correlate closely with observed values. Statistically, the odds are greater than 1000 to 1 against this agreement occurring by chance;

2) The equilibrium oxygen content of a molten alloy bath is determined primarily by the metal chemistry, inclusion composition, and temperature;

3) The oxygen equilibrium which is established in the finishing stages of melting and in the ladle can be estimated from the reaction:

$$\underline{Si} + 2\underline{O} = (SiO_2)$$

where (SiO_2) represents SiO_2 in a complex inclusion;

4) The activity of (SiO_2) is an important variable in determining the equilibrium oxygen levels. This activity is strongly influenced by manganese, titanium, and aluminum. In the absence of aluminum and titanium, the activity of (SiO_2) is a function of the Mn/Si ratio in the metal. When aluminum and/or titanium are present in addition to manganese, the activity of (SiO_2) is reduced below the values predicted from the Mn/Si ratio;

5) The combined influence of manganese, titanium, and aluminum on the activity of (SiO_2) can be estimated by graphical additions of their individual effects; and

6) A wide variety of finishing slags was encountered in this study; it appears that the major function of such slags is to isolate the melt from the atmosphere allowing equilibrium to be established between the melt and its products of deoxidation.

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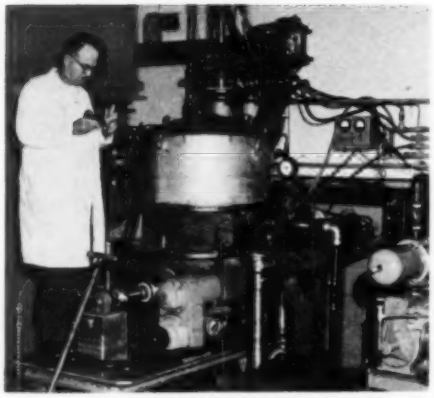
BUREAU OF MINES METALLURGICAL RESEARCH

Above, Square wave polarograph for analyses of trace metals in solution

This, the second article in a series on the Bureau of Mines, describes the Bureau's metallurgical research program and its management. The third article will set forth the operation of a typical metallurgical research center.

Summarized from an article
by H. G. Iverson



Skull furnace designed specifically for producing shaped castings of tungsten.

In an age when ever-mounting demands for purer and better metals must be supplied from lower grade and increasingly refractory resources, metallurgical research is of major importance.

New and improved methods of extraction are needed to obtain optimum recoveries and high-grade products at low cost. Improved materials prepared from mineral and metal products, which are needed in industrial and defense applications must have properties that meet exacting specifications. High-purity metals, complex alloys, and clad and ceramic products must remain strong and ductile at unusually high and low temperatures and be able to resist chemical corrosion. To put such superior products into effective use, new methods of working and plating them must be developed.

In attacking these problems the Bureau of Mines has broadened its metallurgical research program markedly in recent years. In addition to the extractive studies it has performed for several decades on commonly used mineral raw materials, the Bureau now conducts research on extraction, purification, and fabrication of other metals and non-metallics that have become significant in modern engineering applications and also seeks a better understanding of their properties. The Bureau's capabilities in this important work are measured by the equipment of its research centers and laboratories and by the talents and skills of the professionals who staff these installations. Headquarters management works through these field research establishments, which carry out the program it plans and directs.

Facilities

The Bureau of Mines' metallurgical research is conducted at seven centers and five associated laboratories. The centers are at Albany, Ore., and Reno, Nev. (with associated laboratories at Boulder City, Nev., and Berkeley, Calif.), Salt Lake City, Utah (with a laboratory at Tucson, Ariz.), Rolla, Mo., and Minneapolis, Minn. (with a laboratory at Bruceton, Pa.), College Park, Md. (with a laboratory at Norris, Tenn.), and Tuscaloosa, Ala.

The physical aspects, size, and number of buildings at each of the 12 research establishments vary considerably, reflecting the times and conditions under which they were established, as well as changing national and local requirements. At most centers, metallurgical studies are confined to a single building, and at the largest and newest ones —Minneapolis and Reno—the buildings were planned specifically for research. They are functional in design and provide the flexibility needed to accommodate many different types of investigations. At two other prominent centers—the Albany Metallurgy Research Center in Oregon and the Boulder City Metallurgy Research Laboratory in Nevada—the Bureau occupies structures that were originally built to serve other purposes. Metallurgical research at these establishments is conducted in separate and somewhat dispersed buildings.

An approximate indication of each metallurgy research center's size can be given by the number of personnel it employs. As of March 1961, the total personnel ranged from 37 at Tuscaloosa, Ala, to 193 at Albany, Ore. There are 13 full-time scientists or technologists at Tuscaloosa and 85 at Albany; the

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rest are supporting personnel. The average at each of the seven centers is 56 full-time scientists or technologists and 124 total; this latter figure includes an average of 17 physical-science technicians or aides and an average of five university-employed scientists who work part time for the Bureau. Facilities of the seven research centers are adequate to permit a substantial increase in technical personnel.

The variety of the investigations conducted by the Bureau requires high competency in virtually all phases of metallurgy, physical and inorganic chemistry, chemical and ceramic engineering, and mineralogy. In addition, this work demands well-developed ability in specialized mathematics and physics. Moreover, the Bureau's scientists and engineers must be supported by skilled and inventive craftsmen.

In the large spectrum of research projects conducted by the Bureau, there are opportunities for both the specialist and the generalist. By their able performance of challenging assignments, both types of researchers have won recognition for the Bureau and for themselves. Three of the four Arthur S. Flemming Awards attained by the Bureau in recent years have gone to metallurgists, and specialists in this field have received citations from Government agencies and technical societies, along with frequent invitations to present papers at national and international scientific meetings.

Functional capabilities

The wide variety and scope of the Bureau's metallurgical research program can be shown by the many disciplines required. These include such unfamiliar subdisciplines as mineral bacteriology which is a relatively new field, involving studies of the action of micro-organisms in decomposing minerals and freeing desired elements. Another example is image heating. The image furnace consists essentially of two identical paraboloidal mirrors facing each other with a source of energy—such as an electric arc or a carbon electrode—at the focus of one. The radiation emitted by the energy source, transmitted as a parallel beam to the second mirror, is reflected to the focus of the latter. The resulting small zone of high energy input is intense enough to produce temperatures of approximately 3000°C. and is completely divorced from the vapors and electrical disturbances of the energy source itself.

Process metallurgy differs from the other major disciplines in that it is reserved for investigations that concern the technical development of complete processes for recovering desired commercial-grade products from ores. This usually involves a combination of two or more extractive-metallurgy disciplines.

Except for iron-blast-furnace studies, all of this metallurgical research is on a small scale; the Bureau does not presently operate large pilot or prototype plants to test commercial applications of processes. Such installations have been operated in the past during emergencies that called for demonstrating methods of using domestic resources for producing strategic metals or metallic compounds.

The Bureau's experimental, 4-ft-hearth-diameter iron blast furnace, a relatively large installation and until recently the only one in the United States, is used primarily for research. Experiments with this furnace led to the development of fuel injection which, significantly, has been adopted by a number of commercial blast furnaces to achieve increased efficiency and productivity.

Application of the many metallurgical disciplines to research concerning about half the known elements, in one form or another, implies the development and use of new experimental techniques. Such methods often cannot be accommodated by commercially-available laboratory equipment. Therefore, special apparatus must be designed, constructed, and tested to meet experimental requirements.

Emphasis on disciplines

The major disciplines—hydrometallurgy, pyrometallurgy, electrometallurgy, physical chemistry, and physical metallurgy—are emphasized in Bureau programs. Moderate emphasis is placed on mineral dressing, analytical research, and process metallurgy. This year the work in radiological chemistry, apart from that involving use of radiological techniques in analytical research, will see the construction of a 155,000-curie cobalt-60 gamma facility at Albany, Ore., and the beginning of research to determine the effects of gamma radiation on certain minerals.

The metallurgical fraternity is acquainted with most of the Bureau's studies. However, its analytical research, particularly that relating to trace or microquantity impurities, is comparatively recent and, perhaps, less well known. An organized program in this area was first begun only about five years ago, and relatively few publications describing findings have been issued as yet.

Despite the newness of this program, accomplishments thus far have been substantial enough for the Bureau to be selected by NATO's Advisory Group for Aeronautical Research and Development (AGARD) as a participant in analyzing samples of high-purity tungsten for trace impurities. Also worth noting is the fact that Bureau-made determinations of oxygen in columbium, by both vacuum fusion and inert-gas fusion, were included in a report by the American Society for Testing Materials.

The Bureau's excursion into analytical research —it employs virtually all available wet-chemical, ion-exchange, solvent-extraction, and instrumental techniques, including radiological methods—grew out of experiments in producing high-purity metals. These experiments have been so successful that it is by no means unrealistic to envision an ultimate need for analytical techniques that will detect impurities in terms of parts per billion. Hence, advanced analytical research must be conducted to satisfy the metallurgist's requirements for more precise determinations.

The many scientific disciplines represented in the Bureau are applied in both extractive and materials research. The latter, dealing primarily with the properties of metals and minerals and their behavior under varying conditions, currently is receiving an increasing amount of attention. Bureau studies cover extraction, purification, reduction, refining, alloying and other preparations, and the physics, properties, and behavior of high-temperature metals, alloys, and ceramic materials in varying environments. Many elements, in pure, mineralogical, or other chemical forms, and many other materials are involved, including tungsten, rare-earth metals and oxides, molybdenum, columbium, tantalum, hafnium, boron, cobalt, nickel, chromium,

zirconium, and vanadium; such light metals as beryllium, titanium, aluminum, magnesium, and lithium; the ferrous metals and alloys, including iron, steel, and manganese; members of the rare-and-precious family such as germanium, rhenium, scandium, tellurium, yttrium, cesium, and hafnium; base metals such as copper, lead, zinc, antimony, and cadmium; and radioactive elements such as thorium and uranium. Among the non-metallics on which research is in progress are fluorine, sulfur, phosphorus, synthetic mica and asbestos, and hard refractory materials such as borides and carbides.

The kind of work conducted at a research center or laboratory depends substantially on the special capabilities of its staff and the character of its physical plant. Mineral dressing is a major function at three centers and a moderate activity at one. Hydrometallurgy is a prominent activity at two centers and a moderate activity at three others. Electrometallurgy, process metallurgy, and ceramics are each prominent at three different centers and moderate at three others. Pyrometallurgy is prominent at two centers and moderate at one; physical chemistry receives major emphasis at two centers and moderate emphasis at two; and product analysis is prominent at three centers and moderate at one. The large number of metallurgical disciplines and subdisciplines, together with the many commodity and material problems, permits a wide latitude of research efforts without duplication of work other than that intended for checking purposes, and this is relatively small.

Management

The scientists at any one metallurgy research center are under the supervision and direction of a research director whose primary objective is to use all the capabilities at his disposal to best advantage on the research problems assigned.

Coordination and expeditious achievement of the objectives of the overall metallurgy-research program, as carried out by the seven centers, are the responsibilities of the Headquarters Branch of Metallurgy Research, which assigns research problems and reviews progress on individual projects, recommending changes and providing guidance as necessary. The Branch also proposes new projects and evaluates projects proposed by personnel in the field, and reviews and coordinates reporting of research findings for publication.

Tungsten research, an example

Albany Metallurgy Research Center: Recent pyrometallurgical research included metallothermic bomb reduction of tungsten oxide, using calcium and magnesium, and calcium and aluminum as reductants; and arc melting of the regulus yielded a high-purity metal. Tungsten-base alloys containing thorium or hafnium were prepared by bomb coreduction of the mixed metal chlorides. Physical chemistry techniques were used in preparing purified tungsten hexachloride, which was reduced by hydrogen to make high-purity tungsten metal powder. Physical metallurgical approaches were used in refining tungsten. Tungsten rods were zone-melted, zone-refined, and evaluated by bend testing, swaging and rolling, electrical-resistance measurements, and analysis of impurities. Tungsten alloys containing rare-earth elements and platinum-group metals were prepared and evaluated for certain physical properties and for oxidation resistance at 900°C. In casting studies, sound ingots and shaped castings of tungsten were sought.

Reno Metallurgy Research Center: Physical chemistry, electrometallurgy, and analysis were the principal disciplines applied in tungsten research. Physical chemistry was emphasized in thermodynamic studies to measure heats of formation of sodium ditungstate and sodium tetratungstate. Also included were experiments in extracting tungsten from ores or concentrates by chlorination and purification of the chlorides. Electrometallurgical studies were directed toward winning tungsten directly from ores or concentrates by fused-salt electrolysis, which also was used in refining experiments to obtain a high-purity metal. Electrowinning continued to be successful in extracting tungsten metal directly from raw materials. In analytical research, work to develop spectrochemical procedures for analyzing high-purity tungsten was completed.

Salt Lake City Metallurgy Research Center: Hydrometallurgical methods were applied in extracting tungsten from a phosphate-bearing scheelite ore. Autoclave leaching of the ore and recovery of tungsten from the leach solutions by countercurrent solvent extraction techniques were used successfully to obtain a tungsten product containing molybdenum as the principal impurity.

Rolla Metallurgy Research Center: Physical chemistry, physical metallurgy, and analysis were the principal research disciplines applied to tungsten. The physical-chemistry studies involved vapor-vapor reactions between hydrogen and tungsten hexafluoride in depositing high-purity tungsten as coatings on graphite and on rhenium-coated graphite shapes. This research was highly successful. Work in physical metallurgy involved hardness testing of the high-purity tungsten produced and studies of a series of compacted and sintered tungsten-cobalt alloys. Research to develop analytical methods for determining microquantities of impurities in tungsten was pursued, using instrumental techniques and chemical pre-concentration of impurities.

College Park Metallurgy Research Center: Experimental work in electrometallurgy and analytical studies were the research activities on tungsten. Electrometallurgical studies on cladding various metals with tungsten by fused-salt electrolysis produced tungsten-coated sheets of molybdenum, stainless steel, and other metals. Analytical research for quantitative determination of trace impurities in high-purity tungsten metal paralleled similar investigations at the Reno and Rolla Metallurgy Research Centers.

Summary

The metallurgical research program of the Bureau of Mines is conducted at seven research centers and their associated laboratories, strategically located across the Nation and under the general supervision and guidance of a Branch of Metallurgy Research in the Bureau's Washington, D. C., headquarters. In meeting the Nation's changing needs for research on a variety of mineral problems, the Bureau has developed a program that is both well-integrated and flexible. This program offers, to the generalist and the specialist, opportunities for interesting and challenging careers and excellent prospects for achieving recognition in a rapidly advancing field of technology.

FABRICATION AND PROCESSING OF REFRACTORY METALS

Consideration is given to the basic principles underlying the fabrication and processing of refractory metals. The effect of primary fabrication on sheet properties of molybdenum, along with anticipated areas of improvement are discussed. The properties available in columbium alloy sheet containing 10 pct Mo and 10 pct Ti are presented.

by C. P. Mueller

The processing and fabrication of refractory metals has advanced steadily in recent years. This advance has been necessitated by the growing demands of the missile and space industries for structural materials which will withstand temperatures above 2000°F. The refractory metals which are being developed for these specific applications are mainly alloys of columbium, molybdenum, tantalum, and tungsten. When processed and fabricated by proper techniques, these metals exhibit the required properties of high strength and ductility at elevated temperatures.

One of the major difficulties encountered when attempting to fabricate components from these materials is the lack of adequate room-temperature fabricability. This lack of fabricability is, in part, due to the contamination of the materials by oxygen and nitrogen during mill processing. Significant advances have been made in preventing and eliminating this contamination, but much additional work is required if continued improvement in material properties is to be obtained. Improvements in raw material chemistry and selective heat treatments have proven advantageous to the processing and resultant properties of all of the refractory metals.

When considering the processing or fabrication of the refractory metals—columbium, molybdenum, tantalum, and tungsten—it is most convenient to place them in two categories, the first category being the metals, molybdenum and tungsten, which have a low solubility for interstitials, and the second category representing columbium and tantalum which have a high solubility for interstitials. When considering the first category it is necessary to have carbon present in the arc-cast product to act as a deoxidizer and reduce the oxygen to below 20 ppm. In subsequent processing, it is necessary to maintain this oxygen level, and also nitrogen, as low as possible. Therefore, the methods of processing the as-cast material are quite critical and necessitate the development of techniques which will minimize contamination by these impurities.

The metals in category two can tolerate substantially larger quantities of interstitials because of the much higher solubilities for oxygen, nitrogen, and carbon. Thus, heavy contaminated layers are formed during processing when the materials are processed in an air environment at elevated temperatures. This contamination is quite detrimental to mechanical properties and can lead to early failure of components produced therefrom.

The data described in this paper is limited to commercially available materials, and the processing details described relates to molybdenum and molybdenum alloys. However, the precautions necessary during the fabrication of this metal are no different from those of the other refractory metals, although the mechanisms for accomplishment may be substantially different.

Processing variables

The control of raw material chemistries has been a problem that has plagued the refractory metal industry since its inception. This problem has been the greatest single deterrent to the development of this class of materials. Molybdenum and tungsten metal powders have been produced in quantity for 50 years for use in the lamp industry. However, the materials used for this purpose do not possess the purity required for arc-cast molybdenum and tungsten.

In contrast to the problems relating to molybdenum and tungsten, it has only been in the last five years that high-purity columbium and tantalum metals have been produced by electron-beam melting techniques. The availability of this high purity material has made possible research on alloy systems involving these base metals.

In the case of molybdenum, the highest purity raw material that was available in substantial quantity until several years ago, was metal powder reduced directly from molybdenum trioxide. To further refine this material, it is necessary to dissolve in ammonium hydroxide, filter, evaporate, and thus form a pure crystallized compound of ammonium molybdate. Reduction by hydrogen then produced the pure metal. Comparison of the residual elements in sintered electrode bars and arc-cast ingots of molybdenum prepared by both techniques is shown in Table I. Neither the carbon nor the oxygen is a result of the method of powder preparation; the carbon is intentionally added during blending to control the oxygen.

The question may be raised as to the significance of these values. The greatest single benefit to be derived is the decrease in variability which occurs in the molybdate-reduced material. This variability manifests itself in melting, as well as all other processing operations. As an example, we may consider the problem of primary processing by extrusion. In the case of trioxide-reduced material,

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Table I. Comparison of Residual Elements in Sintered Electrode Bar and Arc-Cast Molybdenum Ingots Made from Trioxide and Molybdate Powders

	Sintered Electrode Bar		Arc-Cast Ingot	
	Molybdate Reduced, ppm	Trioxide Reduced, ppm	Molybdate Reduced, ppm	Trioxide Reduced, ppm
Al	10	50	5	<10
Mg	<1	10	<1	<10
Ca	3	20	<1	<10
Na	<10	20	<1	<10
K	<10	20	<1	<10
Si	30	400	20	100
Fe	30	100	20	50
Cr	<10	50	5	20
Ni	<10	50	5	<10
Co	<10	50	5	<10
Cu	<10	20	<1	<10
W	50	50	50	<10
Mn	<10	10	<1	<10
Sn	<10	100	<1	20
Pb	<10	10	<1	<10
C	300	300	200	200
O_2	100	100	5	<10

the extrusion pressures will run 15 to 20 pct higher on the average than for arc-cast material produced from metal reduced from molybdate. These higher pressures may not appear significant, but to facilitate an adequate breakdown of the as-cast structure, the pressures required for extruding molybdenum and molybdenum alloys are at the limit of available press capacity. Thus, when trioxide-reduced metal is used, a percentage of the billets are simply not capable of being extruded with presently-available equipment.

Along with this problem of higher average extrusion values, the problem of variability is also persistent. The pressure required to extrude material reduced from molybdate will vary ± 4 pct from the average value. For material reduced from trioxide, the pressure will vary as much as ± 10 pct from the average. Thus, the metal reduced from molybdate possesses not only a higher purity level but a substantial reduction in variability from lot to lot. The figures quoted are representative for pure molybdenum. The problem becomes much more severe when considering alloys, such as Mo + 0.5 pct Ti or Mo + 0.5 pct Ti + 0.1 pct Zr. In these instances, it is an absolute necessity to use powder reduced from the molybdate if consistently successful extrusions are to be obtained.

The question of purity in tungsten is much the same as molybdenum. As the purity of the starting material increases, the variability and difficulties decrease. Thus, it is important that high-purity consistent metal powders be made available if substantial progress is to be made in the production of arc-cast tungsten mill products.

For columbium and tantalum metal, the electron beam melting technique is supplying raw material of relatively low variability. The problem that arises here is one of adding controlled amounts of interstitials to this raw material to develop desired properties. When adding controlled amounts of oxygen and carbon to arc-cast ingots, the homogeneity of the resultant ingot presents the most formidable task. The variability encountered in these additions is the reverse of the problem to eliminate them; nevertheless, it presents just as difficult a task. A better means of control of both residual metallic impurities and interstitial levels is required if more complex columbium and tantalum alloys are to be produced on a commercial scale. With the work that is presently underway by

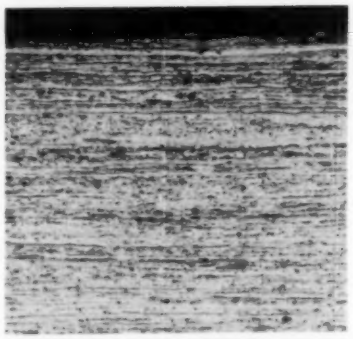


Fig. 1 — Hot-cold rolled Mo + 0.5 pct Ti sheet 0.050-in. thick, showing contamination at surface, 200X.

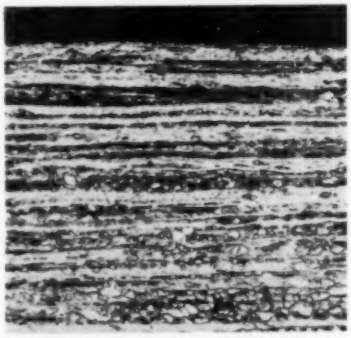


Fig. 2 — Hot-cold rolled Mo + 0.5 pct Ti sheet 0.050-in. thick partially recrystallized, showing effect of contamination at surface, 200X.

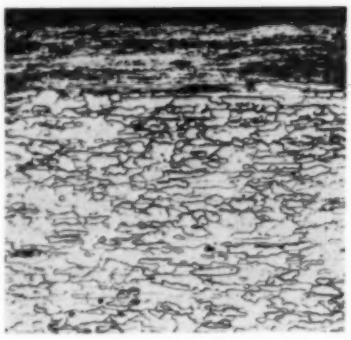


Fig. 3 — Hot-cold worked Mo + 0.5 pct Ti sheet 0.050-in. thick fully recrystallized core, 200X.

various organizations, this problem of control will undoubtedly improve as more experience is gained.

In the past, it was common practice to take a round extrusion and forge it to a sheet bar prior to rolling. Today, this practice is no longer followed, and sheet bar is extruded directly from the ingot; this practice is followed for columbium, molybdenum, and tantalum. The conversion of tungsten has not gained the sophistication of the other refractory metals and is still processed by forging.

The advantages that are gained by direct extrusion of sheet bar are many, but the most important are as follows:

1) More uniform cold work throughout the sheet bar,
2) Elimination of contamination by forging,
3) Improved sheet quality,
4) Decreased processing time, and
5) More uniform plate and sheet properties.

When a sheet bar is produced by extrusion, the resultant product need only be heat treated and conditioned prior to rolling to the desired gauge. The problems encountered in sheet production which result in inconsistent properties are many and varied. To discuss all of these problems would be the subject of a paper in itself; however, one of the most important areas of concern, that of con-

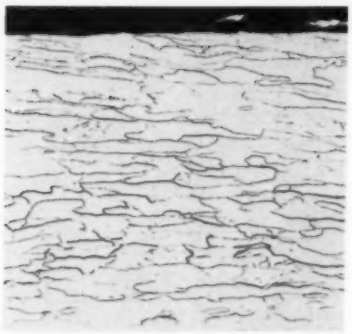


Fig. 4 — Hot-cold worked Mo + 0.5 pct Ti sheet 0.050-in. thick fully recrystallized, no contamination, 200X.

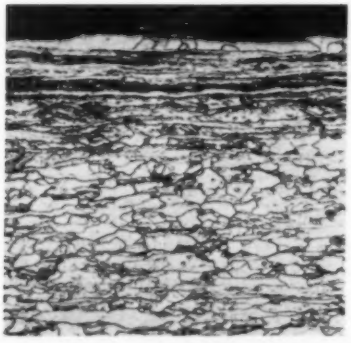


Fig. 5 — Hot-cold worked Mo + 0.5 pct Ti sheet 0.150-in. thick partially recrystallized, contaminated surface removed by hydrogen treatment, 200X.

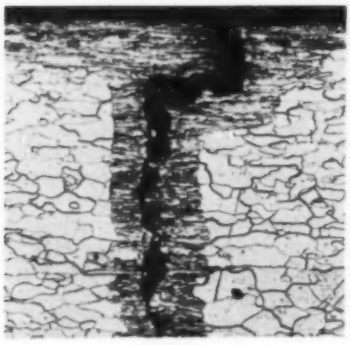


Fig. 6 — Hot-cold worked Mo + 0.5 pct Ti sheet 0.005-in. thick recrystallized core, contamination due to crack in foil, 1000X.

tamination during sheet production, is treated at this time.

Rolling of molybdenum alloys in an air environment imparts considerable contamination into the surface of the sheet. If the atmosphere used for heating the sheet bar or mold-out is oxidizing, oxygen and nitrogen will be picked up by the material, and as a result, the final sheet will exhibit a contaminated surface layer. Since several mold-out stages are required to reduce the sheet bar to the desired gauge, the material must be heated to rolling temperatures several times. Adding to the time of exposure in oxidizing conditions, present equipment limitations require that the sheet be rolled in air. Thus, the sheet can be exposed to air at elevated temperatures during the heating and rolling cycles. If a reducing atmosphere is used for heating, the exposure time is greatly reduced and the contamination reduced.

To illustrate this effect metallographically, it is necessary to partially or fully recrystallize the material so that confusion between cold-worked structure and contamination is not made. Fig. 1 is a photomicrograph of a 0.050-in. thick molybdenum + 0.5 pct Ti sheet in the hot-cold worked condition. Close observation shows evidence of contamination on the surface, but care must be taken so as not to confuse a higher degree of cold-work at the surface with the contaminated layer.

In Fig. 2, the same material has been partially recrystallized. As you move from the core to the surface, a decreasing amount of recrystallization is observed. At the extreme surface no recrystallization has occured. The effect of contamination on recrystallization can, thus, be readily determined. If the temperature is increased to obtain complete recrystallization of the core, the effect of the contamination can be more readily observed as in Fig. 3. When comparing these three photomicrographs, it is realized that contamination is difficult to separate from cold-work structure for the untrained observer.

If the proper care is taken to prevent contamination during heating, rolling, and stress-relieving treatments as well as surface conditioning between rolling steps, the structure of Fig. 4 results. This sample has essentially no contamination, for it was processed under ideal non-contaminating conditions. Molybdenum sheet material exhibiting this degree of cleanliness will exhibit improved properties and will lend itself more readily to fabrication.

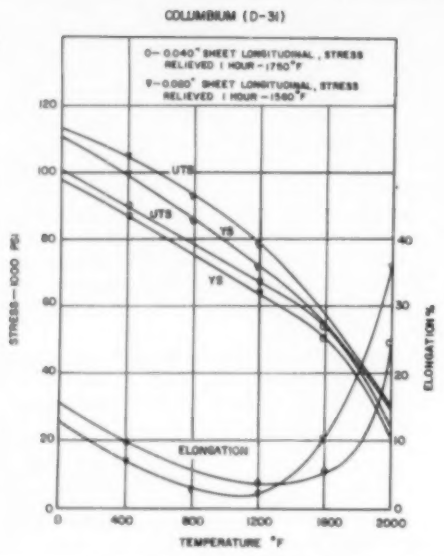
To prepare metallographic samples that will depict the described phenomena, it is very important to control the atmosphere in which the samples are being heat treated. If the samples are heated in an oxidizing atmosphere, contamination can result from the recrystallization treatments. If samples are treated in a reducing atmosphere, but were previously contaminated, the results of Fig. 5 will appear. In this example, the specimen was treated in a dry hydrogen atmosphere, and reduction of the oxygen at the surface occurred. However, a contaminated layer still exists, except that it is now sub-surface.

There is another interesting point to bring out at this time, and that is the question of the effect of contamination on sheet defects. In Fig. 6 a 0.005-in. sheet is shown with a crack running in from the surface. This crack could have been initiated by any one of the many types of sheet defects that can occur during processing. It is noticed that contamination around the crack is as severe as on the surface of the sheet. This degree of contamination can be expected to occur around any sheet defect.

In the above illustrations, it is seen how the important processing techniques for producing molybdenum sheet can effect the resultant microstructure. This structure in turn determines the mechanical properties as well as the fabricability of the sheet produced. As additional experience is gained in the proper handling of these materials, the properties of the materials should improve significantly.

Sheet production of the other refractory metals results in the problem similar to that depicted for molybdenum. However, in the case of columbium and tantalum, it is necessary to vacuum anneal to lessen the tendency for contamination during heat treatment. Nevertheless, the processing problems associated with contamination are quite similar, even though the contamination mechanisms are often different.

As an example of the advancements that have been made in sheet production in another of the refractory metal groups, we can consider the alloy D-31 containing 10 pct Mo and 10 pct Ti, balance Cb. Several months ago the largest sheet produced was approximately 6 in. wide, but through the joint efforts of DuPont and Universal-Cyclops, tech-



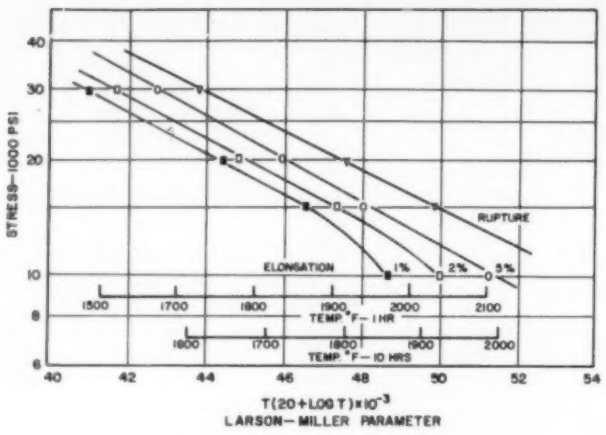


Fig. 7—Left, Hot tensile data for 0.020 and 0.040-in. sheet. Fig. 8—Above, Creep rupture data for 0.060-in. sheet stress relieved after hot-cold work for 1 hr at 1750°F, tested in vacuum.

niques have been developed to produce large sizes of sheet. The results of this effort a sheet, 0.020 in. thick, 25.5 in. wide, and 81 in. long. This material is now available in large sizes at all thicknesses down to 0.020 in.

Some mechanical property data on D-31 sheet material is shown in Figs. 7 and 8. Fig. 7 shows hot tensile data for 0.020 in. and 0.040 in. sheet up to 2000°F. Of particular interest is the minimum in ductility observed at 1200°F for both gauges. This minimum is related to the recrystallization temperature, and it can be seen from the curves that the ductility recovers approximately 100°F lower for the 0.020-in. sheet. This corresponds almost exactly to the difference in stress relieving temperature employed for the two thicknesses.

Fig. 8, is a Larson-Miller plot of creep rupture data on 0.060 in. D-31 sheet. This figure summarizes the creep data on this alloy over the temperature range from 1500° to 2000°F. The data was generated on material that had been hot-cold worked then stress-relieved for 1 hr at 1750°F. All of the testing was done in vacuum at pressures of 10^{-5} mm of Hg.

In all refractory metal sheet materials, as the amount of cold work increases, the recrystallization temperature decreases. The minimum temperature for 100 pct recrystallization of D-31 sheet at various thicknesses is shown in Fig. 9. This curve was determined by metallographic examination after heating for 1 hr in vacuum at the respective temperatures.

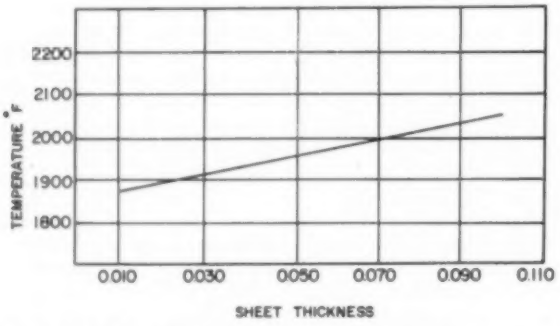


Fig. 9—Minimum temperature for 100 pct recrystallization of D—31 sheet on heating 1 hr in vacuum.

By utilizing proper processing techniques, the degree of contamination in D-31 sheet can be kept to a minimum. When processing this material from 2 in. thick to 0.020 in., there was no detectable increase in oxygen, nitrogen, and carbon. The analysis of the sheet indicated: 500 ppm O, 70 ppm N, and 60 ppm C. To further show that contamination and/or laminations were not present, the stress-relieved sheet exhibits a 1-T bend in both the longitudinal and transverse directions. The results of these experiments indicate that D-31 sheet can be produced on a commercial scale using conventional facilities when an understanding of the problems involved is taken into consideration during the processing steps.

Fabrication

Before consideration is given to the fabrication of a specific shape from one of the refractory metals, it is important that the service conditions under which the material is to be subjected are clearly defined. For example, the environment of the application, the stress levels and required ductilities, the temperature levels anticipated, and the time period should be defined prior to selection of a material for fabrication. In many instances, a material will meet one or several of these requirements but not all of them.

In considering any of the refractory metals for high-temperature applications, the problem of atmosphere must be considered. The alloys of the columbium and tantalum system are severely contaminated by oxygen and nitrogen at elevated temperatures, while molybdenum and tungsten form volatile oxides which evaporate from the surface and result in loss of metal thickness. If the environmental conditions, combined with the temperature, are unfavorable it may be necessary to coat the materials to protect them. On the other hand, the atmosphere may be lean in oxygen and nitrogen, and even though the temperature is high enough to effect considerable contamination, it will not occur because of the lack of contaminants.

Fig. 10 shows the effect of oxidation rate of molybdenum at 2080°F vs. altitude. As the operat-

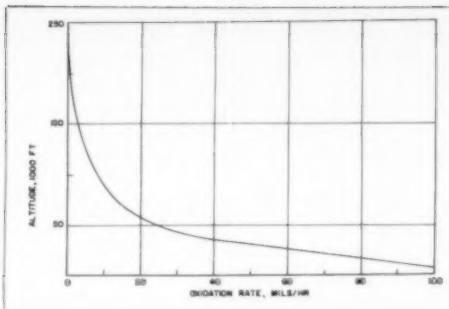
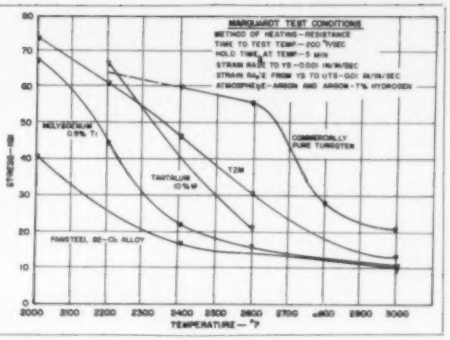


Fig. 10—Left, Oxidation rate of molybdenum at 2080°F vs. altitude.

Fig. 11—Right, ultimate tensile strength of five uncoated refractory sheet materials.



ing altitude is raised, the oxidation rate decreases until at an altitude above 250,000 ft, the oxidation rate becomes negligible. Another means of considering the effect of altitude is the metal loss in thickness vs. time at temperature. For an operating time of 2 hr at 2200°F, the metal loss at sea level is 0.070 in. per side. For the same time and temperature, the metal loss is 0.0017 in. at 95,000 ft and less than 0.001 in. at 200,000 ft. From this type of information, a decision can be made as to whether or not the fabricated part must be coated for protection. The same types of data can be developed for any alloy of the refractory metals, and a comparison can be made of the relative resistance to environment at any altitude.

Another consideration that must be made prior to the selection of a given material is the mechanical properties. In Fig. 11, a comparison of the ultimate tensile strengths of some of the commercially available refractory metal alloys is given. The test conditions were such that all samples were tested under identical conditions. It is interesting to note that at 3000°F, the tensile strengths of Mo + 0.5 pct Ti and Fansteel 82 are essentially the same, while the TZM alloy is approximately 40 pct higher. On the other hand, commercially-pure tungsten is almost double TZM at 2600°F but only about 50 pct higher at 3000°F.

In all missiles and space vehicles, weight of the components is of prime importance. Fig. 12 compares the ultimate tensile strength-to-weight ratio of several refractory metal sheet materials. In contrast to Fig. 11, the TZM alloy is slightly superior to pure tungsten from 2600° to 3000°F. At 2600°F the strength of these two alloys is double the Mo + 0.5 pct Ti, Fansteel 82, and Ta 10 pct W alloys. From the data presented in Fig. 12, it is observed that at 3000°F all of the alloys considered have essentially the same strength when compared on a strength-to-weight basis. From this data, the necessity of comparing strength data on a strength-to-weight basis is apparent; otherwise a weight penalty may be encountered in the final structure.

Refractory metals as components

After consideration has been given to the requirements of the structure or component to be fabricated and the limitations of the materials to be used are realized, final selection of the alloy can be made. This final selection is often based not only upon the requirements of the structure but is quite frequently influenced by the availability of the material in the desired shape. The availability factor is predicated upon the demands of industry for the particular material desired. Mills cannot stock all sizes, and until standardization occurs throughout the refractory metals industry, the problem of availability through long delivery dates will persist.

Aside from the problems previously set forth, there is the added difficulty of reproducibility. Fig. 13 graphically depicts the mechanical property range of 28 forged molybdenum rings. These rings were machine-rolled from arc-cast, extruded, and recrystallized billet stock. The rings varied from 12.5 to 15 in. in outer diameter with a wall thickness ranging from 1 to 1.5 in. From this figure it is seen that the elongation varies from 7 to 27 pct, while the reduction in area varies from 8 to 29 pct.

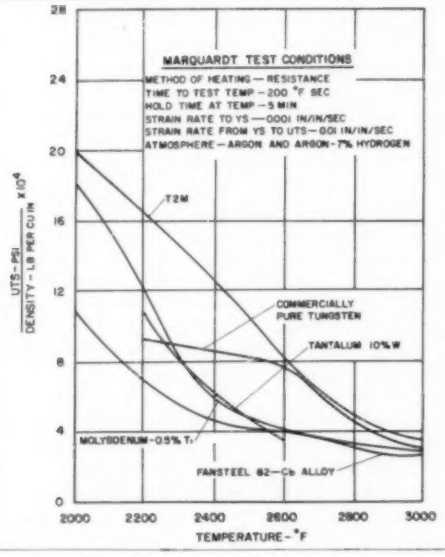
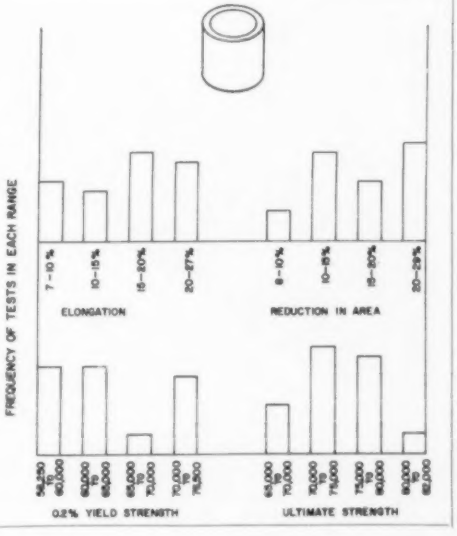


Fig. 12—Left, Ultimate tensile strength-to-weight ratio of five uncoated refractory sheet materials.

Fig. 13—Right, Mechanical property range on forged molybdenum rings for 28 tests, material in stress relieved condition, 12.5 to 15 in. O.D. x 1.5-in. wall section.



At the same time, the 0.2 pct yield strength has a spread from 56,250 to 76,300 psi, while the ultimate strength varies from 65,000 to 82,000 psi. There is no particular maximum in the distribution of these properties at the center of these ranges, except possibly in the case of ultimate tensile strength.

The design requirements of such a component must be based on the minimum properties developed as a result of the fabricating operations. Even though properties substantially above these minimum requirements are developed 75 pct of the time, they cannot be used because of the large degree of variability. It is felt that one of the major factors in this variability in properties is the control of raw material chemistries as has previously been noted. In addition, variations in processing procedures certainly contribute to the observed variation. Until adequate control of starting material can be realized, it is expected that much of this variability will persist. Within the past year, substantial progress has been made in this direction by working with larger powder lots and limiting the impurities to much smaller levels and ranges. This will be reflected in more uniform property data as development work progresses.

The component we have just described involves the use of a heavy section for fabrication and subsequent utilization. In many applications, it is necessary to utilize thin sections in intricate shapes. Such a section is shown in Fig. 14, which is a composite refractory metals assembly designed and fabricated by Republic Aviation Corp. This structure represents the product of a development program which has as its purpose the manufacture of a representative section of the F-105 brake door from a combination of three refractory metals: tungsten, molybdenum, and columbium. The selection of the three different materials is based upon the specific requirements of each section of the component. The leading edge, which will be exposed to the highest temperature, is made from tungsten. The temperature is lowered as the distance from this leading edge increases and the utilization of molybdenum and molybdenum alloys becomes practical. The trailing edge is much cooler than the other portions of the structure and is made from columbium alloy materials.

It is anticipated that the use of composite structures will increase in the future. Their use will be based upon utilizing the best properties or combination of properties of all of the refractory metals and alloys. Much more experience is needed in the testing of complete structures to determine the extent to which composites can fulfill the requirements which one material of construction cannot meet.

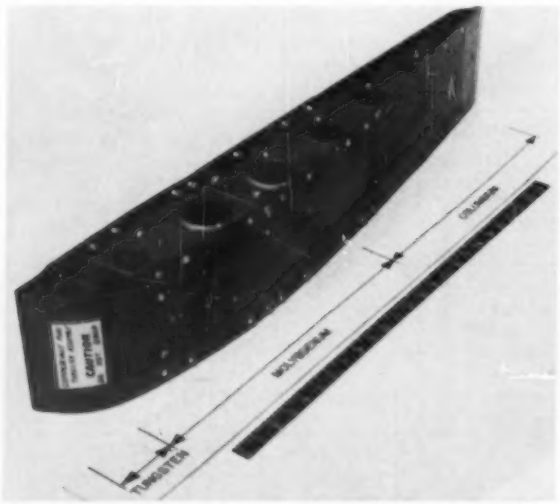


Fig. 14—Composite refractory metals assembly. Courtesy Republic Aviation Corp.

In these two illustrations, some of the problems and possible solutions to the fabrication of refractory metal components has been shown. There are many additional problems. The question of fasteners, expansion joints, coatings, and many other problems must also be factored into the over-all picture. Of prime importance is the requirement for fabricating some of these sheet components at temperatures as high as 1200°F. The handling requirements and tooling to perform such operations is, in most cases, not available and, when it is available, the operating cost is quite high.

Future considerations

An attempt has been made to set forth briefly the state-of-the-art of the processing and fabrication of refractory metals as carried out by present day techniques. The advances that have been made over the past several years are most encouraging; however, considerably more development is required before the real potential of the refractory metals can be realized.

In both the processing and fabrication areas, we have been progressing by what can be described as an evolutionary curve. The evolution was at first quite rapid in developing improved properties, but as time passes, it becomes more and more difficult to obtain substantial property improvement unless a new concept or revolutionary development occurs. Such revolutionary developments have occurred in the past in the metals industry.

As examples of these revolutionary influences in metallurgy, the following can be cited. The bessemer converter spurred the advance of the steel industry at a time when progress was quite slow. The aluminum industry got its impetus from the development of the Hall process. Massive sections of molybdenum were not available until the development of vacuum arc-melting became a reality. Many more citations could be noted where a revolution has taken place to advance a metal industry.

In all of the major technological advances the solution to the problem was a break-through in equipment utilization or development. These processing equipment revolutions were capable of advancing the state-of-the-art, and thus generating another evolutionary curve. Even though the total progress of an industry or field of endeavor is depicted by a straight line, a closer look at the individual components of that line will show the growth by evolution and revolution.

At the present time, it is felt that a revolution is progressing within the refractory metal field. This revolution is again an equipment break-through which will allow the processing fabrication of these materials in a non-contaminating environment. The InFab (Inert Fabrication) facility built by Universal-Cyclops Steel Corp. for the Department of the Navy is designed to permit the forging and rolling of refractory metals in a high-purity argon atmosphere. With the absence of contamination that is anticipated, many of the problems previously cited should be eliminated and improved properties result.

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GENERAL SECRETARY—ERNEST KIRKENDALL
ASST. SECRETARIES—J. B. ALFORD, H. N. APPLETON, J. C. FOX, R. W. SHEARMAN, C. J. HICKS
ASST. TREASURER—JOHN LYNCH
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ASST. SECRETARY—D. C. JOHNSTON

NEWS OF YOUR PROFESSION

Program Announced For 1962 Symposium On Refractory Metals

The program for the 1962 Refractory Metals Symposium, cosponsored by the IMD Refractory Metals Committee and the Chicago section of AIME, has recently been announced by the program chairman, I. Perlmutter. The conference will be held April 12-13 at the Morrison Hotel in Chicago.

The opening session on Thursday morning will concentrate on the Ductile-to-Brittle Transition in Refractory Metals, with papers on *Current Theories*, by Walter Owens, University of Liverpool; *Effects of Solutes*, by R. I. Jaffee, G. T. Hahn, and A. Gilbert, Battelle Memorial Institute; and *Effects of Variables*, by L. L. Seigle, General Telephone and Electronics Laboratories.

The afternoon session on April 12 will include the following papers: *Preparation of Ultra-Pure Refractory Metals*, by M. Korchynsky and A. R. Gahler, Union Carbide Metals Co.; *Substructure in Refractory Metals*, by M. Cohen, Massachusetts Institute of Technology, S. Weissman, Rutgers University, and B. S. Lement, Manufacturing Laboratories, Inc.; *Mechanism of Alloy Strengthening in Refractory Metals*, by J. H. Bechtold, R. W. Armstrong, and R. T. Begley, Westinghouse Electric Corp.; and *Diffusion in Refractory Metals*, by E. J. Rapperport, Nuclear Metals Inc., and C. S. Hartley, Aeronautical Systems div., USAF.

A social hour for conference registrants is planned as the culmination of the first day's activities.

The morning session on Friday, April 13, will include the following papers: *Effects of Alloying Elements on Oxidation Behavior of Refractory Metals*, by W. M. Fassell, Jr. and J. N. Ong, Jr., Aeronutronic div. of Ford Motor Co.; *Protective Coatings for Refractory Metals*, by M. A. Levinstein, General Electric Co.; and *Joining of Refractory Metals*, by W. N. Platte, Westinghouse Electric Corp.

The following papers have been scheduled for the concluding session

(Continued on page 933)

EXTRACTIVE METALLURGY OF ALUMINUM SUBJECT OF ANNUAL MEETING SYMPOSIUM

A special International Symposium on The Extractive Metallurgy of Aluminum will be one of the highlights of the AIME Annual Meeting in New York City's Astor Hotel February 18-22.

The symposium, sponsored by the Extractive Metallurgy Division, will have a total of eight technical sessions, including two on the *Technology of Alumina Production*; two on *Carbon Technology in Aluminum Production*; three on the *Technology of Primary Aluminum Production*, and a session on *New Processes and Materials of Construction*.

EMD's Long Range Planning Committee planned the symposium, proceedings of which will be published at a later date by Interscience Publishers Inc. This is the same committee which planned the symposium on Extractive Metallurgy of Copper, Nickel, and Cobalt for the 1960 Annual Meeting. Copies of these proceedings are still available for $22.50 (member's price, $18.00).

The Iron and Steel Division's Howe Lecturer will be Morris Cohen of Massachusetts Institute of Technology, who speaks February 20.

EMD will sponsor sessions on copper, uranium, zinc, physical chemistry, chlorination, refractories, and hydrometallurgy. There will also be a hydrometallurgy session sponsored jointly with the Minerals Beneficiation Division.

The Iron and Steel Division has made tentative plans for six and one half technical sessions during the meeting. There will be a *Steelmaking* session on Monday morning and a session on *Blast Furnace Technology* in the afternoon. On Tuesday morning there will be a session on *Iron Ore Reduction*. Wednesday calls for a morning session on *Thermodynamics of Molten Oxides*, and an afternoon session on *Applications of Thermodynamics*. A session on *Physical Chemistry of Liquid Iron Alloys* will be held on Thursday morning; *Gases in Liquid Steel* will be the subject of the afternoon session.

The Institute of Metals Division will present 12 technical sessions and six abstract sessions. *Properties of Thin Films* will be the subject of two technical sessions on Monday (Feb. 19), morning and afternoon. There will also be a Tuesday afternoon session on *Recovery and Recrystallization* and another on Wednesday afternoon. *Effects of Microstructure on High Temperature Properties* will be the subject of sessions on Monday morning and Tuesday afternoon. On Thursday there will be morning and afternoon sessions on *Electronic Structure and Alloy Chemistry of Transition Elements* and on *Liquid Metals Corrosion*.

The Institute of Metals Lecture will be presented on Wednesday morning, Feb. 21. The speaker will be Academician G. V. Kurdjumov of the Central Scientific Research Institute for Nonferrous Metallurgy, Moscow, USSR.

Albert J. Phillips, vice president and director of research, American Smelting and Refining Co., has been named to present the Fourth Extractive Metallurgy Division Lecture.

Call for 1962 Dues

Notice is hereby given that dues for the year 1962 are payable Jan. 1, 1962 as follows: Members and Associate Members, $20; Junior Members for the first six years of Junior Membership, $12, and thereafter $17; Student Members (including an annual subscription to a monthly journal), $4.50.

Dues bills were mailed in early November. Prompt payment will assure uninterrupted receipt of the publications desired in 1962. If, for any reason, a bill is not received within a reasonable time, AIME headquarters should be notified.

Opening the 55-year-old cornerstone box from the 39th Street building are (l to r) Willis F. Thompson, president of United Engineering Trustees, Miss Frances Selig, and Joseph E. Johnson, president of the Carnegie Foundation for International Peace.

1906 Cornerstone Box Opened In Ceremonies At Engineering Center

A sentimental ceremony of the opening of the cornerstone box of the Engineering Societies Building took place on September 28. The lead container had been tapped into place in the cornerstone of the old building on May 8, 1906 by Mrs. Andrew Carnegie.

Among the contents of the box was a gold plaque engraved with the words that Mr. Carnegie had written to the five professional engineering societies stating that, "it will give me great pleasure to devote, say, one and a half million dollars for the erection of a suitable home for you all in New York."

The box also contained newspapers and magazines of the year 1906, a certificate attesting to Mr. Carnegie's election to membership in the Institute of Mining Engineers, and gold, silver, nickel, and copper coins of the day. All contents of the box were in excellent condition, although the silver, nickel, and copper coins had dulled a bit.

Among those present for the opening of the box was Miss Frances Selig, who was present in 1906 when the box was placed in the cornerstone. Miss Selig has been an employee of the Society of Mechanical Engineers for 55 years.

The box was opened at a neighborhood reception attended by engineering society representatives and guests from the United Nations, the Carnegie Endowment for International Peace, and the Boys' Club of America.

Mrs. Winifred Gifford Is Executive Secretary Of Women Engineers

Mrs. Winifred D. Gifford has been appointed executive secretary of the Society of Women Engineers. She was formerly assistant editor of the JOURNAL OF METALS. From this position she was appointed secretary to the General Secretary of AIME. Among her activities in this post she compiled the annual Honors Booklet, the Committee Directory, attended board meetings to record minutes, and attended Annual Meetings to assist the secretary at various functions.

Born in New York City, Mrs. Gifford is a graduate of the College of New Rochelle. She taught in a New York City High School and was secretary to the Bursar of Rockefeller Institute for Medical Research.

Her mariage to Joseph C. Gifford interrupted her business career. Following the death of her husband, Mrs. Gifford joined the staff of AIME.

As a free-lance editor, Mrs. Gifford is currently assistant editor of the AIME Blast Furnace Proceedings, and continues to compile the AIME Honors Booklet. She also edits various publications for outside firms.

As executive secretary of SWE, Mrs. Gifford's offices will be in Room 305 of the United Engineering Center.

Southwestern NOHC Holds Two-Day Meeting In Kansas City

Kansas City was honored as the temporary geographical headquarters for the globe-trotting members of the Southwestern section of the National Open Hearth Steel Committee during their annual two-day conference, October 5-6. Registrants come from the four points of the section's compass—Peoria, Illinois; Birmingham, Alabama; Monterrey, Mexico; and Pueblo, Colorado; some 156 in all. Participants were treated to a day of plant trips, followed by an all-day technical session at the President Hotel. The theme was Quality—From Raw Materials to Finished Product.

Control of Bar Surface Quality was the title of the paper presented by J. V. Florchak, assistant chief metallurgist, Gary works, U. S. Steel Corp. The production of bars of top quality is the concern of both steel producers and users. Bar surface quality was shown to be influenced by such factors as *temperature* (best in the range 2850°-2900°F), *conditioning practice* (pickling is best), *conversion practice* (best is double-converted semi-finished), *rolling reduction* (rounds under 2 in. are best), *silicon content*, *manganese content*, and *carbon content*. The effect of *deoxidation* on billet surface quality is most important, with best to poorest practice in the decreasing order: (1) rimmed and capped; (2) semi-killed; (3) killed, coarse-grained; (4) killed, fine-grained. The speaker concluded by urging customers to provide producers with performance data on steel products. This paper will be published as the lead-off paper in Volume 13, *Bar and Allied Products* of The Metallurgical Society Conference Series in cooperation with Interscience Publishers, Inc. This paper appeared in the November issue of JOURNAL OF METALS, pp 825-828.

A motion picture, *The Germ*, from the U. S. Steel Corp. library, was shown after an introduction by E. G. Balog, assistant chief quality control metallurgist, with Tennessee Coal and Iron div., Fairfield, Ala. The importance of producing a quality product to please and keep customers was stressed. This film has proved very effective in employee training programs.

Problems of Hot Metal Quality was presented from the point of view of a blast furnace operator by G. W. England, Granite City Steel Co., Granite City, Ill. Extraction of iron from ores by a blast furnace utilizes a pyrometallurgical process at least 4000 years old. Even today the operator can exert only a de-

(Continued on page 933)

Fourth Mechanical Working Conference

FLAT ROLLED PRODUCTS

Wednesday, January 17, 1962 • Pick-Congress Hotel • Chicago, Illinois

Sponsored by the Mechanical Working Committee, Iron and Steel Division, The Metallurgical Society, and Chicago Section, The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc.

TUESDAY, JANUARY 16, 1962

Registration

6:00—9:00 pm — 2nd Floor Foyer

JANUARY 17, 1962 WEDNESDAY MORNING

Quality Factors in Deep Drawing Sheets

8:45 am—12:30 pm — Great Hall

Opening Remarks:
T. E. Dancy, Vice Chairman, Mechanical Working Committee.

Chairmen:
R. S. Burns, Director—Metallurgical Research, Research and Technology, Armco Steel Corp., Middletown, Ohio.
W. H. Mayo, Manager—Process Control Metallurgy, U.S. Steel Corp., Pittsburgh, Pa.

1. **A Method of Simulation By Torsion for Determining the Influence of Hot Rolling Conditions on Steel Structure:**
C. Rossard and P. Blain, Rolling Mill Dept., IRSID, St. Germain-en-Laye, France

2. **Grain Orientation in Drawing Quality Cold Rolled Steel:**
R. H. Heyer, Supervising Research Metallurgist, Research and Technology, Armco Steel Corp., Middletown, Ohio

3. **Relationship Between Texture, Hot Mill Practice, and Deep Drawability of Sheet Steel:**
R. L. Whitley, Supervisor of Mechanical Metallurgy, and D. E. Wise, Research Engineer, Bethlehem Steel Co., Bethlehem, Pa.

4. **Strain Marking on Cold Rolled and Annealed Sheets:**
J. F. Butler, Senior Research Engineer, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

5. **Heat Transfer Between Continuous Strip and a Roll:**
H. L. Taylor, Chief Research Engineer, Research and Development, and J. D. Elliott, Metallurgist, Research and Development Department, Inland Steel Co., East Chicago, Ind.

Luncheon

Time: 12:30 pm
Place: Great Hall
Price: Included with Registration Fee
Speaker: P. H. Smith, Chairman, Mechanical Working Committee
Subject: *Future of the Mechanical Working Committee*

JANUARY 17, 1962 WEDNESDAY AFTERNOON

New Developments in Flat Rolled Products

2:00 pm—5:00 pm — Great Hall

Chairmen:
J. N. Imel, Superintendent—Strip Sheet Department, Pittsburgh Works, Jones & Laughlin Steel Corp., Pittsburgh, Pa.
A. G. Forrest, Assistant to Chief Metallurgist, Republic Steel Corp., Cleveland, Ohio

1. **Use of Open Coil Annealing in Processing Cold Rolled Sheets:**
S. H. Kalin, Assistant Division Chief—Sheet Products Division, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa., and E. M. Puchy, General Supervisor, Process Metallurgical—Silicon, Irvin Works, U. S. Steel Corp., Dravosburg, Pa.

2. **Galvanized—From Free Spangle to Spangle Free:**
Nelson E. Cook, General Superintendent of Galvanizing, Wheeling Steel Corp., Wheeling, W. Va.

3. **Columbium Treated Steels:**
C. L. Altenburger, Technical Assistant to the President, Great Lakes Steel Corp., Ecorse, Michigan.

4. **Columbium Bearing Steel in High Pressure Line Pipe Service:**
A. G. Barkow, Superintendent of Inspection, Natural Gas Pipeline Co. of America, Chicago, Ill.

Social Hour

5:00 pm—7:00 pm — Rendezvous Room

General Information

Registration:
The registration fee including the cost of the lunch and a copy of the proceedings is $13.00 for AIME members and $15.00 for non-members.
Advance registration may be made by sending a check to J. F. Griffin, U. S. Steel Corp., Room 3424, 525 William Penn Place, Pittsburgh, Pa.

Pick-Congress Hotel:
Located at 520 South Michigan Ave., Chicago 5, Ill.

AROUND THE SECTIONS

San Francisco section, AIME, met at the Engineers' Club on October 11 with 116 members and guests attending. The speaker for the evening was H. S. "Pete" Fowler of the Mountain Copper Co., Martinez, Calif. He discussed *A Mining Engineer's View of Three Great African Dam Projects—Aswan, Kariba, and Volta.*

On November 15, the San Francisco section met with the student section from Stanford University.

The annual Christmas Party is planned for December 13 at the Engineers' Club.

Richmond section, AIME, met September 25 to hear a talk by Alexander Gakner, assistant vice president of Royer & Roger Inc. He discussed *Russia and Its Petroleum Industry.*

On November 6, R. R. McNaughton, President of AIME, discussed *Canada and Canadians* at the section's meeting. The wives of members and guests were invited to hear Mr. McNaughton's talk, which was presented at the William Byrd Hotel.

Chicago section, AIME, held its first meeting of the 1961-62 season on October 4 at the Armour Research Foundation of Illinois Institute of Technology. Fifty-one members and guests attended the meeting.

The Labor Department Looks at the 60's was the title of the main address of the evening which was delivered by James J. Reynolds, Assistant Secretary of Labor. Mr. Reynolds is widely experienced in labor-management relations, both by virtue of his work in private industry and as a former member of the National Labor Relations Board.

November 1 was Student's Night for the Chicago section. The speaker for the evening was G. E. Darcy, Jr. of Watertown Arsenal, who discussed *Materials for Solid Propellant Rocket Motors.*

Ohio Valley section, AIME, held its *National Officers Meeting* October 12 in Columbus. Carleton C. Long, Vice President of AIME and director of research for St. Joseph Lead Co., was the featured speaker. Dr. Long was honored at a luncheon sponsored by Battelle Memorial Institute and later discussed section activities with local section officers. Dr. Long's topic for the evening dinner meeting was *Cooperative Research by Metal Trade Associations* in which he described the functions of the trade associations serving the copper, lead, and zinc industries.

The November meeting of the Ohio Valley section was held on November 16. The meeting included a tour of Battelle Memorial Institute's Nuclear Research Center near Columbus. Major General Harold F. Harding addressed a dinner meeting at the Lincoln Lodge in Columbus later in the evening. General Harding, commanding general of Ohio's 83rd Infantry Division, spoke on *Nuclear Weapons: Life and Death.*

Pittsburgh section, AIME, has nominated section officers to serve during 1962. They are Charles L. Potter, chairman; James H. Bechtold, vice chairman; James G. Tilton, secretary; and Frank P. Shankwiler, treasurer. A ballot is being taken by mail.

Pittsburgh section, IMD, held its first technical meeting of the season on October 5 at Skibo, Carnegie Institute of Technology. The technical speaker for the meeting was W. C. Leslie of the Edgar C. Bain Laboratory for Fundamental Research, U. S. Steel Corp.

Dr. Leslie presented a talk on *Recovery, Recrystallization of Cold Worked Metals.* The speaker first reviewed the current state of knowledge of the annealing of cold-worked iron and other metals. New information was then presented—principally obtained by transmission electron microscopy—concerning the structure of cold-worked iron and zone-refined, high-purity iron. The structure of cold-worked iron, orientation relationship, recovery, recrystallization, and grain growth were the main topics covered in considerable detail along with experimental data.

It was pointed out that the dislocation structure in cold-worked polycrystalline iron is affected by the amount, type, and rate of plastic strain, and the temperature at which the straining is done. The formation of cell structure as a function of deformation was illustrated. It was shown that the recovery of the initial flow stress of strain-hardened iron is analogous to that in other metal and is associated with a decrease in average dislocation density and the formation of regular networks of dislocations.

(Continued on page 933)

a new book

of special interest to the nuclear metallurgist . . .

published under the sponsorship of The Metallurgical Society of AIME

Extractive and Physical Metallurgy of Plutonium and its Alloys

The Proceedings of a Technical Symposium sponsored by the Nuclear Metallurgy Committee of the Institute of Metals Division, and the Titanium, Uranium, and Uncommon Metals Committee of the Extractive Metallurgy Division, The Metallurgical Society of AIME. San Francisco, February 16-17, 1959.

Edited by W. D. WILKINSON, Argonne National Laboratory

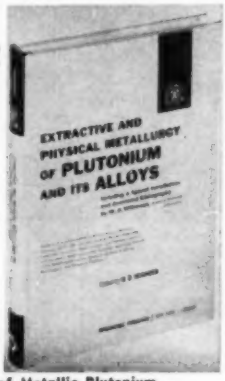
The addition to these Proceedings of an introductory chapter on the metallurgy of plutonium and of an extensive annotated bibliography has made this volume of even greater value to metallurgists working in this particularly important field. Mr. Wilkinson both edited the Proceedings and provided the new material.

CONTENTS

Introduction to Plutonium Metallurgy

EXTRACTIVE METALLURGY

- Alternative Routes for the Conversion of Plutonium Salts to Metal and Their Recovery Problems
- Calcium Reduction of Plutonium Halides to Metal



- Preparation of Metallic Plutonium
- Distribution of Plutonium and Selected Impurity Elements between Nitrate Solutions and Tri-n-butyl Phosphate
- The Preparation of Plutonium Halides for Fused Salt Studies
- Removal of Fission Product Elements from Plutonium by Liquidation

PHYSICAL METALLURGY

- Some Principles of the Alloying Behavior of Plutonium
- The Plutonium-Cerium Diagram
- Plutonium-Zinc Phase Diagram
- Metallography of Alpha Plutonium
- The Etching of Plutonium and Its Alloys by Cathodic Bombardment
- A Study of the Transformation Kinetics of Alpha, Beta, and Gamma Plutonium
- Some Experiments in Zone Refining Plutonium
- Behavior of Some Delta-Satilized Plutonium Alloys at High Pressure
- Annotated Bibliography

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J. B. Austin (above), addresses the Inaugural Session of the Special Meeting. Below, members of The Iron & Steel Institute of London register in the lobby of the United Engineering Center for the Inaugural Session.

The British Are Here

The Inaugural Session of The Iron and Steel Institute's visit to the United States was held Thursday afternoon, October 19, at the United Engineering Center. The British visitors, guests of The Metallurgical Society of AIME, made extensive plant trips in the US and Canada.

At the Inaugural Session, the Welcoming Address was made by J. S. Smart, Jr., President of The Metallurgical Society. The Response was by Sir Charles Goodeve, President of The Iron and Steel Institute. Sir Charles was made an Honorary Life Member of AIME, and Dr. James B. Austin, vice president of U. S. Steel Corp., became an Honorary Vice President of The Iron and Steel Institute. Dr. Austin delivered the main address of the afternoon on *Three Centuries of Progress in the American Iron and Steel Industry.*

* * *

Below, E. O. Kirkendall, General Secretary of AIME, congratulates Sir Charles Goodeve, president of The Iron & Steel Institute on his election to honorary life membership in AIME.

Metal Powder Group Has Clinic-Conference

The Metal Powder Industries Federation held its annual Powder Metallurgy Clinic-Conference during September with Hoeganaes Sponge Iron Corp., Riverton, N. J. as host.

The morning was devoted to a tour of the Hoeganaes plant, where sponge iron powders and high-alloy powders are manufactured. Luncheon was held at the Cherry Hill Inn, followed by the afternoon clinic-conference. This was an open session of questions and answers concerning the industry with a free participation from members of the Assn. Discussions concerned metal powder quality control, suggested product improvement (metal powders), and the general welfare of the powder metallurgy industry.

Call For Papers

Papers on refractory metals are being solicited by the IMD Refractory Metals Committee for presentation at the 1962 Fall Meeting of The Metallurgical Society, to be held in New York, Oct. 29-Nov. 1. Sessions are currently planned to cover Group V and Group VI metals.

Abstracts should be submitted no later than Feb. 1, 1962, to: C. P. Mueller, Refractomet div., Universal-Cyclops Steel Corp., Bridgeville, Pa., or L. S. Richardson, Westinghouse Research Labs., Beulah Rd., Churchill Boro, Pittsburgh 35, Pa.

Joint Meeting

Minnesota Section - AIME Annual Meeting and Twenty-Third Annual Mining Symposium University of Minnesota

January 15-17, 1962 • Hotel Duluth • Duluth, Minnesota

Minnesota Section—AIME Annual Meeting

General Chairman—Minnesota Section—Eugene P. Pfleider
Program Chairman—Norwood B. Melcher

MONDAY, JANUARY 15

9:30 am—Morning Session
Session Chairman—M. E. Volin

1. **Anionic Flotation of Silica—A New Look:** by D. W. Frommer, M. M. Fine, Minneapolis Metallurgy Research Center, US Bureau of Mines, Minneapolis, Minn., and L. Bonicatto, M. A. Hanna Co., Hibbing, Minn.
2. **Magnetic Roasting of Knob Lake Lean Ores:** by H. E. Neal and R. M. Smith, Iron Ore Co. of Canada, Schefferville, Quebec, Can.
3. **Grate Kiln Pelletizing at Humboldt:** by D. M. Urich and R. W. Berkhahn, Cleveland-Cliffs Iron Co., Ishpeming, Mich.

12:15 pm—Luncheon—Speaker to be Announced

1:45 pm—Afternoon Session
Session Chairman—F. H. Bunge

1. **High-Intensity Magnetic Separation of Iron Ores:** by Ossi E. Palasvirta and J. Robert Andreachi, Oliver Iron Mining Division, U. S. Steel Corp., Duluth, Minn.
2. **Experimental Preparation of Prereduced Iron Ore Pellets:** by J. P. Hansen and T. N. Rushton, Minneapolis Metallurgy Research Center, USBM, Minneapolis, Minn.
3. **Pelletizing Butler, Groveland and Carol Lake Concentrates:** by Fred H. Bunge and John S. Wakeman, The Hanna Mining Co., Cleveland, Ohio, and Hibbing, Minn.
4. **Blast Furnace Practice of Tomorrow:** by J. H. Strassburger, E. Ostrowski, and J. R. Dietz, National Steel Corp., Weirton, W. Va.

6:30 pm—Dinner
Speaker—O. Meredith Wilson, President, University of Minnesota, Minneapolis, Minn.

Twenty-Third Annual Mining Symposium School of Mines and Metallurgy and Center for Continuation Study University of Minnesota

TUESDAY, JANUARY 16

9:00 am—Morning Session
Session Chairman—Professor T. L. Joseph

Semi-Taconite and Blast Furnace Performance on Beneficiated Burdens

1. **The Occurrence and Utilization of Semi-Taconite:** by H. H. Wade, Director, Mines Experiment Station, University of Minnesota, Minneapolis, Minn.
2. **The Use of Natural Gas on a Pellet-Sinter-Ore Burden:** by R. W. Liggett, Chairman, Blast Furnace Operating Committee, Republic Steel Corp., Cleveland, Ohio
3. **Natural Gas and Pellet Use at the Ford Motor Company:** by Ralph D. Killian, Jr., Supt., Blast Furnaces, Ford Motor Co., Dearborn, Mich.
4. **Blast Furnace Practice on Beneficiated Burdens at Fairless Works:** by R. H. White, Division Supt., Blast Furnaces, Fairless Works, U. S. Steel Corp., Fairless Hills, Pa.

1:30 pm—Afternoon Session
Session Chairman—Professor Walfrid Been

New Developments in the Iron Ore Industry

1. **New Developments in the Exploration and Investigation of Iron Ore Properties:** by Norman Moberg, Director, Mineral Development, Oliver Iron Mining Division, U. S. Steel Corp., Duluth, Minn.
2. **New Developments in Underground Mining Throughout the Lake Superior Iron Ranges:** by P. D. Pearson, Manager, Ore Mines, Inland Steel Co., Ishpeming, Mich.
3. **New Developments in Open Pit Mining—Minnesota and Michigan Areas:**

by Merlyn Woodle, Manager, Babbitt Division, and Raymond Bertie, Assistant Mine Supt., Reserve Mining Co., Babbitt, Minn.

4. **New Developments in Open Pit Mining—Canadian Area:**
by C. E. McManus, General Manager, Iron Ore Co. of Canada, Sept-Iles, Quebec, Can.

WEDNESDAY, JANUARY 17

9:00 am—Morning Session
Session Chairman—Roland E. Durocher

New Developments in the Iron Ore Industry (Continued)

Pre-Session Film "The Atlantic City Project" (8:30 am)

1. **New Developments in the Beneficiation of Iron Ores:**
by Donald Scott, Continental Sales and Equipment, Hibbing, Minn.
2. **The Atlantic City Project, Wyoming:**
by Stan Cohlmeyer, Project Manager, A. S. Henderson and R. C. Morgan, Columbia-Geneva Steel Division, U. S. Steel Co.
(Presented by Walter A. Hamilton, Supt. of Concentrating)
3. **Meramec Mining Company's Iron Mine at Pea Ridge, Missouri:**
by Elmer Jones, Division Manager, St. Joseph Lead Co., Bonne Terre, Mo.
4. **Marcona Iron Ore from Peru:**
by Earl Herkenhoff, Vice President, Technical Services, Marcona Mining Co., San Francisco, Calif.

Southwestern NOHC

(Continued from page 928)

gree of control over such factors as temperature, slag composition, carbon and sulphur content.

Problems of Scrap Quality was the subject of a paper by L. B. Lindemuth, Jr., open hearth superintendent, Keystone Steel and Wire Co., Peoria, Ill. Quality of scrap used is reflected in quality of product. Application of this principle led to more effective control of copper content of steel produced. A second paper on the same subject was given by Harold Olden, Laclede Steel Co., Alton, Ill. A three-point program was developed to improve the quality of scrap charged: inspection, preparation, and selective charging.

In addition to the formal technical papers, two symposiums were conducted on *Effect of Prolonged Shutdowns on Open Hearth Furnaces*, and on *Furnace Building and Maintenance Techniques*. All companies in the Southwestern section were asked to participate.

L. B. Lindemuth, Chairman of the Southwestern section, opened the session with words of greeting. The technical program was chaired by W. H. Steinheider, Sheffield div., Armco Steel Corp., Kansas City.

The Friday technical program followed a day of plant trips on October 5.

The final festivity of the two-day meeting was the Fellowship Dinner. Robert Criger, division supervisor of employee communications, Sheffield div., served as toastmaster. Speaker of the evening was Thomas Collins, publicity director of the City National Bank and Trust Co., Kansas City, whose address was entitled *You're Greater Than You Think*.

The next technical meeting of the Southwestern section will be held at the Lennox Hotel, St. Louis, February 9, 1962. Next year's Fall Meeting is scheduled for the Broadmoor Hotel, Colorado Springs, Colo., on October 1-2. RWS

Refractory Metals

(Continued from page 927)

of the conference on the afternoon of Friday the 13th: *Consolidation of Refractory Metals*, by James Wong, Wah Chang Corp.; *Conversion of Refractory Metals*, by W. Rostoker, Armour Research Foundation; *Use of Refractory Metals in Advanced Space Power Systems*, by L. Rosenblum and C. Barrett, National Aeronautics & Space Administration; and *Refractory Metals for Re-entry Vehicles*, by E. G. Czarnecki, Boeing Airplane Co.

Final program details and abstracts of papers to be presented at the symposium will appear in the March issue of JOURNAL OF METALS. Programs and registration materials will be mailed to IMD members in advance of the conference.

The Conference Committee plans to publish proceedings of the symposium in the Metallurgical Society Conference Series following the meeting. I. Perlmutter and M. Semchyshen have been named editors of the volume.

Around the Sections

(Continued from page 930)

The addition of alloying elements, viz. manganese to iron, increases the lower yield stress and the rate of strain-hardening of iron and enhances the formation of the cold-worked cell structure. The speaker also pointed out that inclusions or second phase particles can nucleate recrystallized grains by promoting the formation of cells during cold working. Precipitation, controlled so as to occur after cold working but before recrystallization, can be used to change the size, shape, and texture of the recrystallized grains.

On ideas of future research, D. Leslie pointed out the need for calorimetric studies of high-purity iron to evaluate the stored energy of cold work and energy release during recovery and recrystallization. Also, it was pointed out that data on recovery of electrical resistivity following cold work, quenching, and irradiation are unavailable or inadequate to provide information concerning vacancies in iron.

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Cleveland NOHC Holds First Annual Fall Meeting

The Cleveland section, National Open Hearth Steel Committee, held its first all-day technical conference at the Sheraton-Cleveland Hotel, Cleveland, on Friday, September 22, with an attendance of 282. On Saturday, a plant trip was made to Republic Steel Corp.'s No. 2 open hearth shop at Cleveland. Visitors had an opportunity to see a furnace equipped with three oxygen lances, producing 420-ton heats in 5 hr, 40 min on the average, or 55,000 tons per month of 0.07 pct carbon steel.

In his opening remarks, Cleveland section Chairman, Leo C. Svete, superintendent of bessemer and foundry, National Tube div., U. S. Steel Corp., Lorain, Ohio, explained that the Cleveland section, NOHC, was continuing the tradition established many years ago by the Southern Ohio section in holding an Annual Fall Conference in Columbus. The Southern Ohio section was disbanded early this year.

The morning technical session opened with a *Report on Open Hearth Oxygen Steelmaking* by Fred Kyle, assistant open hearth superintendent, Republic Steel Corp., Cleveland. Two of six open hearth furnaces underwent campaigns of 400 heats on each furnace, with oxygen injected through roof lances. The result was an increase in tons per hour produced each month.

Ralph Duffett, Jr., superintendent of open hearths and bessemers, Great Lakes Steel Corp., Ecorse, Mich., continued on the same subject with a description of their experiments at three open hearth furnaces in injecting water through oxygen roof lances. Smoke effluent through the stack was materially reduced. Other studies were made on the effect of water injection on the pickup of hydrogen and nitrogen, the life of furnace roofs, the proper height of lance above bath to avoid excessive splashing, and the quality of steel produced.

Basic Oxygen Furnace Operations were placed in historical perspective and related to the experience of Jones & Laughlin Steel Corp. at Aliquippa, Pa., by J. N. Albaugh, superintendent of steel works. The record in terms of tonnage produced (1960, best year, 840,000 tons), average tph (107.5), average tap-to-tap time (45 min), average time of oxygen on per heat (21 min), and lining life (best record, 305 heats) were described. Operations began at Aliquippa on November 11, 1957.

John A. Glasgow, superintendent of steelmaking, Jones & Laughlin Steel Corp., Cleveland, described operating results from 36 heats produced at their new basic oxygen steel plant since start-up on September 13, 1961. The furnaces were designed to produce 200 tph. Hot metal charge has averaged 75 pct; scrap, 25 pct. Ground was cleared for the new plant on November 13, 1959. This paper, *Cleveland Receives Basic Oxygen Steelmaking*, appeared in the September issue of JOURNAL OF METALS, pp. 625-627.

Electro-Mechanical Data Logging was the subject of a paper by Paul V. Webb, industrial engineer, open hearth department, Republic Steel Corp., Cleveland. A data logging unit is housed in a truck-trailer next to the charging floor of No. 24 furnace. A complete statistical analysis was made from data logging cards sent to their Computer Center. Objective of the study was to obtain reliable data on optimum flow rates during scrap melt-down; optimum flow rates for the deoxidation period; optimum furnace operating temperatures; the best fuel-oxygen ratio; and effect of fuel on refractories. The evaluation of this information will be used in future planning.

Serving as Chairmen of the morning session were Luis Sanchez, div. superintendent, steel works, National Tube div., U. S. Steel Corp., Lorain, and K. G. Schultz, open hearth superintendent, Republic Steel Corp., Cleveland.

Exothermic Hot Tops were described by H. W. Miller, project engineer, Republic Steel Corp. The use of consumable hot tops was investigated first in 1956. They were found to be economical, not detrimental to operation of the soaking pits, and applicable to big-end down ingots.

E. R. Strange, metallurgical supervisor, steel works, Jones & Laughlin Steel Corp., Cleveland, told of their use of exothermic sideboards, 3 in. thick and 10 in. deep, two per ingot, suspended by steel rods. Advantages were summarized as: increase of ingot yield by 4.5 pct; increase of surface quality; decrease of crane movements and consequent time saving through elimination of back pouring; longer nozzle life, with fewer stopper cutoffs; reduction in amount of storage area; and lower hot top breakage. Disadvantages cited were the increase in fumes and odors, and the increased testing and process control required.

A paper on *C and D Hot Top Installation* was given by H. F. Gammons, general foreman of open hearths, National Tube div., U. S. Steel Corp., Lorain. In 1957 clay hot tops were replaced by C & D hot tops, with an increase of yield between 6 to 8 pct. The majority of the tonnage was used for seamless pipe.

The technical session was concluded with papers on *Spraying of Basic Roofs* by Carl Norbeck, open hearth superintendent, Bethlehem Steel Corp., Lackawanna, N. Y., and on *Experimental Basic Roof* by Joe Flowers, superintendent of masonry, Sharon Steel Corp., Sharon, Pa.

Chairmen of the afternoon session were R. E. Minto, works metallurgist, Jones & Laughlin Steel Corp., Cleveland, and W. D. Nielsen, assistant to open hearth superintendent, National Tube div., U. S. Steel Corp., Lorain. Mr. Minto is Secretary-Treasurer of the Cleveland Section, and Mr. Nielsen is Vice Chairman.

The day's activities were concluded with a Fellowship Dinner. The address, *Get Off Your Launching Pad*, was given by Carl C. Byers, a member of the Speakers Bureau of General Motors Corp., and a former superintendent of schools, Parma, Ohio. Dr. Byers prescribed laughter—filled with *optimistic vitamins*—for all. In a talk alternating between the light and the serious, the speaker emphasized the importance of the *three H's*: humor, happiness, and hope.

During Saturday's plant trip, the Executive Board of the National Open Hearth Steel Committee held its annual fall business meeting. In addition to other business, the Board gave its approval to meet in September, 1962, following another all-day Cleveland technical conference. This vote of confidence will assure the continuity of Annual Conferences in Cleveland.

RWS

NOTICE TO AUTHORS

Make sure that manuscripts are typed double-spaced before submitting them to the JOURNAL OF METALS. Failure to do so results in retyping, chance of error, and needless delay. To facilitate matters, submit papers in duplicate and enclose illustrative material such as drawings and glossy photos at the same time. Such illustrations should be suitable for reproduction.

MEMBERSHIP

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Metallurgical Society of AIME

Total AIME members on Oct. 31, 1961, was 35,609; in addition 2,225 Student Members were enrolled.

ADMISSIONS COMMITTEE

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The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

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Ecord, Glenn M., Grand Prarie, Tex.

SPECIAL REINSTATEMENT TO MEMBER

Thruman, Astor L., Youngstown, Ohio

NECROLOGY

Date Elected	Name	Date of Death
1941	Berg, J. Edward	Aug. 9, 1961
1928	Burt, Maxwell S.	Aug. 1954
1936	Colclough, T. P.	Sept. 22, 1961
1955	Decoux, Arthur	Aug. 24, 1961
1938	DeVoogd, N.	Oct. 14, 1961
1912	Flagg, A. L.	Apr. 27, 1961
1955	Griswold, Fred M.	Unknown
1954	Karlsten, Ralph C.	June 27, 1961
1935	Mahoney, R. F.	Oct. 3, 1961
1956	McKee, D. W.	Dec. 24, 1959
1940	Moir, A. D.	May 19, 1961
1948	Mosley, Lafayette C.	Aug. 28, 1961
1948	Rothenhoefer, W.	May 1961

Reuben E. Sommer

Reuben E. Sommer, 62, president and general manager of Keystone Steel & Wire Co., died October 8 at Baden-Baden, Germany where he had been vacationing with his wife. He had been hospitalized about a week.

William K. Sproule

An Appreciation by
P. Queneau and L. Renzoni

Our late colleague, William Kelvin Sproule, (McGill B.Eng., 1936, M.Sc., 1937) devoted his professional career to International Nickel and the advance of extractive metallurgy, including eight years in charge of the company's process research in Canada. Mr. Sproule was a metallurgist's metallurgist with a passion for his chosen field, a chip off the old block since his father had been professor of metallurgy at McGill.

Kel was the leading, indomitable spirit on the team which discovered and developed Inco's pioneering *matte separation* process. He played a significant role in the improvement of the Orford *tops-and-bottoms* process in the late thirties and in the post-war development of important processes for oxygen flash smelting of sulfide concentrates and for recovery of iron and non-ferrous metals from nickeliferous pyrrhotite. Kel had a zest for life and a keen *radar* mind ever searching the horizon of the unknown. He was happiest on skis—a sport in which he excelled—and in the articulate expression of his thoughts. Kel's simplicity of manner and quiet, gentle smile accompanied an outstanding intellect of stubborn integrity. The mining world at large and the metallurgical profession in particular are the poorer for his passing.

T. P. Colclough

Tom Peach Colclough, chief technical adviser to the British Iron & Steel Federation since 1945, died September 22 at his home, Cut Heath, Farnham Common, Buchshire, England.

Dr. Colclough was educated at Manchester and Sheffield Universities, and joined Brown-Firth Laboratories in 1916. He became chief chemist at Park Gate Iron and Steel Co. Ltd., in 1920, and was successively chief metallurgist, open hearth manager, and technical officer. In 1929 he joined H. A. Brassert and Co. as technical director. He was instrumental in the planning and development of Corby, Ebbw Vale and other steelworks.

Following the war Dr. Colclough, as technical adviser to the BISF, was primarily concerned with the development of the British steel industry.

In addition to his other activities, Dr. Colclough was active in research work. He became a council member of the British Iron and Steel Research Association in 1950. In 1954, he received the Bessemer Gold Medal, the highest award of the Iron and Steel Institute, and was elected honorary vice president last May.

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Coming Events

Dec. 4, 1961, Annual Meeting, Arizona Section, AIME, Pioneer Hotel, Tucson, Ariz.

Dec. 4-5, 1961, New York University, Conference on Beryllium Metallurgy, Washington Square Center, NYU, New York.

Dec. 6-8, 1961, 19th Electric Furnace Conference, Penn-Sheraton Hotel, Pittsburgh, Pa.

Dec. 18-19, 1961, Rensselaer Polytechnic Institute and Watervliet Arsenal, Materials Science Conference, Rensselaer Polytechnic Institute, Troy, N. Y.

Jan. 9-11, 1962, Eighth National Symposium on Reliability and Quality Control, Statler Hilton Hotel, Washington, D. C.

Jan. 15-17, 1962, Minnesota Section, AIME, Annual Meeting held jointly with 23rd Annual Mining Symposium, Hotel Duluth, Duluth, Minn.

Jan. 17, 1962, AIME Mechanical Working Conference, Pick-Congress Hotel, Chicago.

Feb. 5-9, 1962, American Society for Testing and Materials, Committee Week and Spring Meeting, Statler-Hilton and Sheraton-Dallas Hotels, Dallas, Tex.

Feb. 15-17, 1962, American Society for Metals, Golden Gate Metals Conference, Fairmont Hotel, San Francisco, Calif.

Feb. 18-22, 1962, AIME Annual Meeting, New York, N. Y.

Apr. 9-11, 1962, National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Sheraton-Cadillac Hotel, Detroit.

Apr. 9-13, 1962, American Welding Society, 43rd Annual Convention and Welding Exposition, Sheraton Cleveland Hotel, Cleveland, Ohio.

Apr. 12-13, 1962, Chicago section, AIME, in cooperation with IMD Refractory Metals Committee, Refractory Metal Symposium, Morrison Hotel, Chicago, Ill.

Apr. 12-14, 1962, AIME Pacific Southwest Minerals Industry Conference, Palace Hotel, San Francisco, Calif.

April 26-28, 1962, AIME Pacific Northwest Metals and Minerals Conference, Ben Franklin Hotel, Seattle, Wash.

May 2-3, 1962, Iron & Steel Institute (London), Annual General Meeting, London.

May 7-8, 1962, Institute of Metals (London), Symposium on Sintered Low-Alloy Steel Engineering Components, London.

May 7-11, 1962, American Foundrymen's Society, Foundry Show, Cobo Hall, Detroit, Mich.

May 11-13, 1962, Uranium section, AIME, Seventh Annual Uranium Symposium, Moab, Utah.

May 27-29, 1962, The Metallurgical Society of AIME, Research Management Conference, Arden House, Harriman, N. Y.

July 2-8, 1962, Iron & Steel Institute (London), Special Meeting in Dusseldorf, Germany, by invitation of the Verein deutscher Eisenhuttenleute.

Aug. 27-29, 1962, AIME 4th Annual Technical Conference on Semiconductors, Benjamin Franklin Hotel, Philadelphia, Pa.

Sept. 19-21, 1962, AIME Rocky Mountain Minerals Conference, Salt Lake City, Utah.

Oct. 20-26, 1962, Sixth World Power Conference, Melbourne, Australia.

Oct. 28-Nov. 1, 1962, Fall Meeting of The Metallurgical Society of AIME, New York City.

Nov. 28-29, 1962, Iron & Steel Institute (London), Autumn General Meeting, London.

Arthur J. Boynton

An Appreciation by Ralph Vaill

Arthur Jefferson Boynton, born in Elyria, Ohio, October 31, 1876, passed away August 17, 1961 while on a business trip in Dallas, Texas. He was a graduate mechanical engineer, class of 1897, Ohio State University and spent the succeeding 63 years as a worker, superintendent, vice president of operations, and since 1924 a consulting engineer in all phases of iron- and steelmaking, including raw materials.

"Pat" as he was known to three generations of iron and steel men, died in the harness in his 85th year, while engaged in new projects for one of his great loves, The Lone Star Steel Company—in which connection it is worthy to note that Pat and his organization held the unique position, in these days, of having designed and built a complete steel plant.

Pat belonged to the generation of the *greats* such as Quincy Bent, Julian Kennedy, Herman Brassert, Heinrich Freyn, Charles Perrin, and Arthur G. McKee, who as engineers, in the correct usage of the word, gave their energy, courage, high intelligence and indefatigable labor to the providing of better means of production.

Pat Boynton was not the least of these indomitable personages. He was known, respected, and loved for his integrity, originality, his modesty, and his loyalty to his profession. Those many leaders of the iron and steel industry whom he served, and who in turn assisted him, knew that Pat Boynton kept the faith.

He was a stalwart always to keep his country strong and right, as he saw the right, and could always be found in opposition to the demagogues. He was a credit to his alma mater, and although renowned for his long vacationless hours at his vocation, he loved good books, and somehow found time to read them. The technical library he built, book by book, for the use of those laboring with him is second to none in any engineering office.

In 1940 he formed his own company, A. J. Boynton & Co., Engineers and Technical Consultants, which had grown to a position of prominence in the service of the iron and steel industry by the time of his death. Its work and its functions will be carried on by those he had gathered together under his name over a period of years.

He was a life member in several engineering societies, and was very proud of his 50-year medal and life membership in AIME, given him in 1954.

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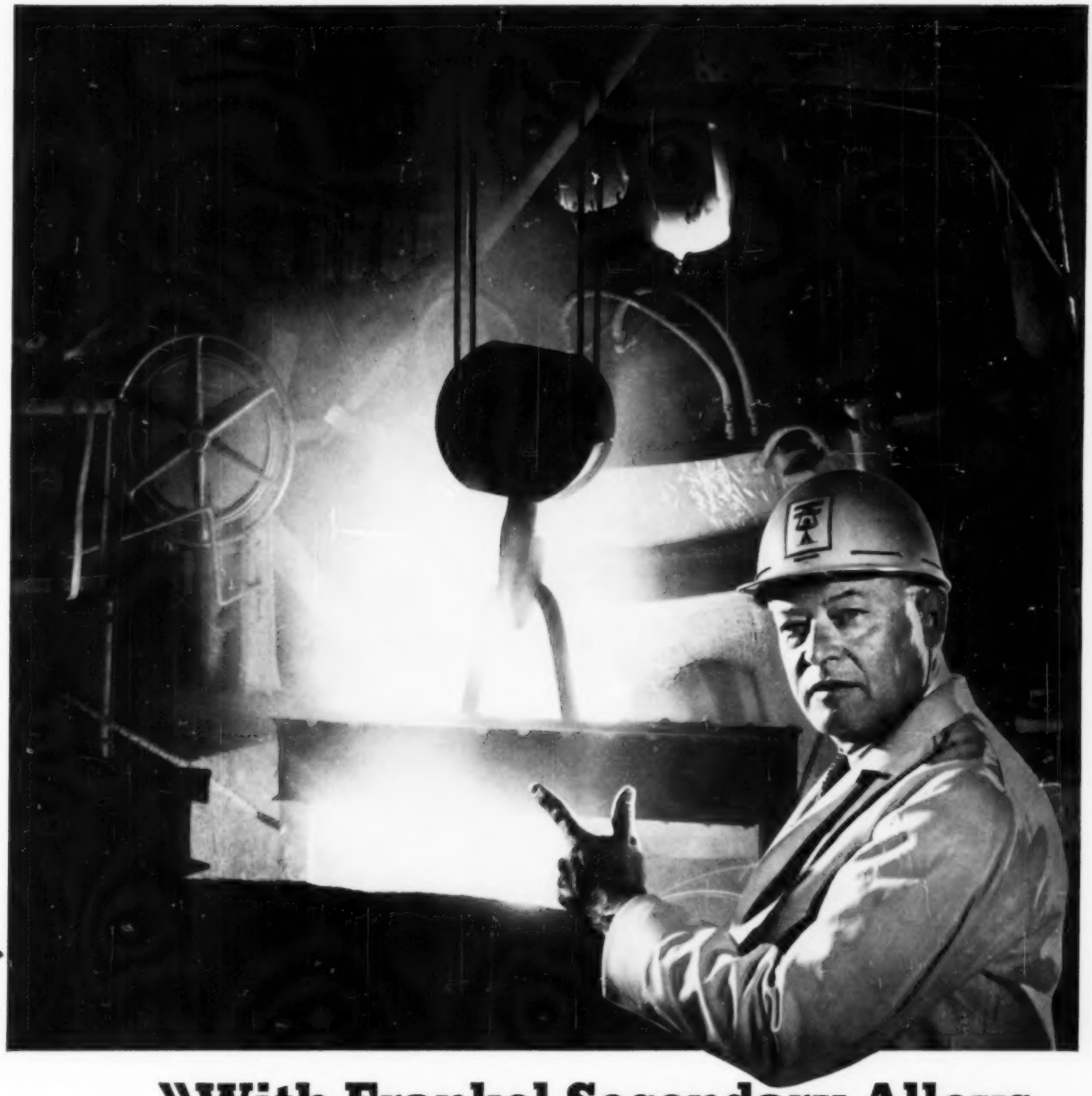

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